The best of both worlds?

An exploratory study on forms and effects of new qualitative-quantitative scenario methodologies

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Abbreviations

AB	Agent Based modeling
APEIM	Asociación Peruana de Empresas de Investigación de Mercados (Peruvian Corporate Association of Market Research)
APPENZELL	Climate Policy Making for Enhanced Technological and Institutional Innovations, B2: Context-specific energy strategies
ATEAM	Advanced Terrestrial Ecosystem Analysis and Modeling
BMBF	Bundesministerium für Bildung und Forschung (German Federal Ministry for Education and Research)
BMU	Bundesministerium für Umwelt, Naturschutz, Bau- und Reaktorsicherheit (German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety)
CA	Consistency Analysis
CGE	Computable General Equilibrium Model
CIA	Cross-Impact Analysis
CIB	Cross-impact balance analysis
CIB&S	Cross-impact balance analysis and simulation
D&V	Descriptors and variants
DE	Descriptor essay
DFG	Deutsche Forschungsgemeinschaft (German Research Foundation)
DOC	Process document
EMF	Energy Modeling Forum Project 21 : Multi-Gas Mitigation and Climate Change
EURURALIS	Discussing the future of rural Europe
FCPV	Foro Ciudades para la Vida, Lima (Forum Cities for Life, NGO)
FFCD	Flood Foresight and Coastal Defense
FN	Field note
FOVIDA	Fomento de la Vida, Lima (Life Aid, NGO working for a sustainable territorial development of Lima)
FSA	Formative Scenario Analysis
GDP	Gross Domestic Product
GEO	Global Environmental Outlook
GSG	Global Scenario Group, Great Transition Initiative
HK	Hannah Kosow
IA	Integrated Assessment modeling
ICT	The future impacts of Information and Communication Technologies
Ifak	Institute for Automation and Communication, ifak e.V. Magdeburg
IL	Intuitive Logics
ILPÖ	Institute of Landscape Planning and Ecology, University of Stuttgart

IMP	Instituto Metropolitano de planificacion, Lima (Urban planning unit of the city of Lima Metropolitana)
IPCC	Intergovernmental Panel on Climate Change
IRMA	Development of flood management strategies for the Rhine and Meuse basins in the context of integrated river management; IRMA-SPONGE INTERREG project
IWS	Institute of Hydraulic Engineering, University of Stuttgart
LiWa	Sustainable water and wastewater management in urban growth centers coping with climate change, concepts for metropolitan Lima (Peru)
MEA	Millennium Ecosystem Assessment
MedAction	Policies for Land Use to Combat Desertification
OECD	Organisation for Economic Co-operation and Development
PRELUDE	Prospective environmental analysis of land use development in Europe
SAS	Story And Simulation
SCENES	Water scenarios for Europe and neighboring states
SD	System Dynamics modeling
SEDAPAL	Servicio de Agua Potable y Alcantarillado de Lima (Water Company of Lima)
SENAMHI	Servicio Nacional de Meteorología e Hidrología, Peru (National Meteorological and Hydrological Service)
SRES	Special Report on Emission Scenarios
SUNASS	Superintendencia Nacional de Servicios de Saneamiento, Peru (National Superintendency of Sanitation Services)
TS	Time series
UBA	Umweltbundesamt (German Federal Environment Agency)
UFZ	Helmholtz Centre for Environmental Research
UNEP	United Nations Environment Programme
UNI	Universidad Nacional de Ingeniería Lima (National University of Engineering)
URNÄSCH	Climate Policy Making for Enhanced Technological and Institutional Innovations B2: Energy strategy of a rural community
VISIONS	Integrated Visions for a Sustainable Europe
WAVES	Water Availability and Vulnerability of Ecosystems and Society in Northeastern Brazil
WWV	World Water Vision Scenarios
ZIRIUS	Research Center for Interdisciplinary Risk and Innovation Studies, University of Stuttgart (until 2012: ZIRN)

Summary

This study analyzes new forms of combined and integrated scenario methodologies, which are used to construct exploratory socio-environmental scenarios. It makes conceptual and empirical contributions to futures studies and to inter- and transdisciplinary environmental and sustainability research.

For 15 years, scenario approaches for the construction of socio-environmental scenarios have been established, which combine qualitative scenario methods with numerical modeling and simulation. They have become state of the art by replacing scenario approaches based on modeling alone. Combined scenario approaches are used to explore the future of socio-environmental systems scientifically, and to supply society and policy makers with the best possible information on possible alternative future developments in climate, biodiversity, land use, water, resources and energy, etc.

Combined scenarios are characterized by a deep methodological and epistemological hybridity, as they combine approaches and perspectives from different realms. This makes their appeal but also raises enormous challenges. At the same time, literature on combined scenarios has thus far provided little conceptual orientation for the comparison, design, assessment and implementation of different forms of combined approaches. In practice, the so-called Story and Simulation (SAS) approach is dominant, coupling intuitive scenarios with simulation, and postulating an iterative refinement of both components.

Against this background, this study explores new avenues: Cross-impact balance analysis (CIB), a systematic-formalized yet qualitative form of systems analysis, is combined with numerical modeling and simulation (CIB&S). As yet, this approach was explored neither empirically nor conceptually in a systematic way. Still, in energy and climate research, the expectation is formulated that this approach might balance the difficulties of combined scenario approaches of the SAS type, especially with regard to traceability and consistency. This study asks whether and how CIB can be combined with numerical modeling and simulation to support inter- and transdisciplinary research teams in constructing qualitative *and* quantitative or integrated exploratory scenarios of socio-environmental systems. It focuses on forms of the combination of CIB&S; on effects on traceability and consistency as well as on further (unintended) effects of the use of CIB within such combinations; and finally on factors influencing these effects.

Combined scenario approaches are conceptualized in this study as inter- and transdisciplinary methodologies. Each application is characterized by an individual social, technical and data-related organization. Based on a review of the literature on combined scenario approaches, central dimensions to characterize forms of the combination of qualitative and quantitative scenario methods are developed. In addition, a model of the typical phases of a CIB&S process is designed. To assess effects, working definitions of scenario traceability and scenario consistency are proposed and operationalized.

This conceptual framework structures the empirical analysis of two exploratory case studies. The first case studies a method demonstration for the German Federal Environment Agency (UBA). In this case, CIB is used to analyze societal framework assumptions of environmental models and to construct plausible sets of assumptions until the year 2030. The second case studies a full pioneer application of CIB&S in the context of a megacity project for the German Federal Ministry for Education and Research (BMBF). In the latter case, CIB is combined with a material flow simulator, to construct integrated scenarios on the possible water futures of Lima, Peru, until the year 2040. Both cases are qualitatively analyzed and interpreted, based on participant observation, interviews with process participants as well as process documents.

The study shows that in different (ideal typical) forms of its combination with numerical modeling and simulation, CIB takes over different functions. The combined form, in turn, is mainly influenced by the position of both components within the process as well as by their degree of integration. CIB&S methodologies can successfully support scenario traceability, and contribute to both the internal consistency of the qualitative scenario component and the consistency between qualitative and quantitative scenario components. The stronger the degree of integration between CIB and simulation model, the stronger these effects. However, integration requires that the models underlying the scenarios, i.e. the conceptual CIB model as well as the numerical modeling and simulation, are made explicit and accessible, are compared with and, if applicable, adapted to each other. In addition, CIB&S approaches can create new checks and balances within combined scenario methodologies, when the definition of scenarios as well as the selection of scenario samples is assigned to the CIB and to the CIB participants. CIB&S approaches seem to be less suitable for the construction of explicitly normative or participatory scenarios. Instead, CIB&S approaches do support the participating experts in better analyzing, structuring and reflecting their knowledge, their assumptions and their ideas on possible future developments of socio-environmental systems. The external users of CIB&S-based scenarios can benefit from the improved accessibility of assumptions on uncertainty and complexity, which underlie the qualitative and quantitative or integrated scenarios, as these become criticizable in the first place.

Overall, this study makes steps toward more conceptually grounded and more reflective research on the diversity of possible variants of combined and integrated scenario methodologies.

Zusammenfassung

Diese Studie untersucht neue Formen kombinierter und integrierter Szenario-Methodologien, die zur Konstruktion von explorativen Mensch-Umwelt-Szenarien eingesetzt werden. Sie leistet einen konzeptuellen und empirischen Beitrag zur Zukunftsforschung sowie zur inter- und transdisziplinären Umwelt- und Nachhaltigkeitsforschung.

Szenario-Ansätze, die zur Entwicklung von Mensch-Umwelt-Szenarien qualitative Szenariomethoden mit numerischer Modellierung und Simulation kombinieren, etablieren sich seit etwa 15 Jahren. Sie lösen allein auf numerischer Modellierung beruhende Szenario-Ansätze als State of the Art ab. Kombinierte Ansätze werden eingesetzt, um zukünftige Entwicklungen von Mensch-Umwelt-Systemen wissenschaftlich zu explorieren, und um Gesellschaft und Politik bestmögliche Informationen über mögliche alternative Zukünfte von z. B. Klima, Biodiversität, Landnutzung, Wasser, Ressourcen und Energie zur Verfügung zu stellen. Kombinierte Szenarien sind durch eine tiefe methodische sowie epistemologische Hybridität gekennzeichnet, da sie Ansätze und Perspektiven aus verschiedenen Bereichen zusammenbringen. Dies macht ihren großen Reiz aus, stellt sie aber auch vor enorme Herausforderungen. Gleichzeitig bietet die Literatur zu kombinierten Szenarien bisher wenig konzeptuelle Orientierung für Vergleich, Bewertung, Design sowie Einsatzbereiche verschiedener kombinierter Ansätze. In der Praxis dominiert der sogenannte Story And Simulation (SAS) Ansatz, in dem intuitive Szenarien mit Simulationen gekoppelt und iterativ verfeinert werden.

Vor diesem Hintergrund geht diese Arbeit neue Wege: Die Cross-Impact Bilanzanalyse (CIB), eine systematisch-formalisierte aber qualitative Form der Systemanalyse, wird mit numerischer Modellierung und Simulation kombiniert (‚CIB&S'). Dieser Ansatz ist bisher weder empirisch noch konzeptuell auf systematische Weise untersuchten worden. In der Energie- und Klimaforschung wird jedoch erwartet, dass er die Schwächen kombinierter Szenario-Ansätze vom Typ SAS vor allem in Bezug auf ihre Nachvollziehbarkeit und Konsistenz ausgleicht. Diese Studie fragt, ob und wie CIB mit numerischer Modellierung und Simulation kombiniert werden kann, um inter- und transdisziplinäre Forscherteams bei der Erstellung von qualitativen *und* quantitativen bzw. integrierten explorativen Mensch-Umwelt-Szenarien zu unterstützen. Im Fokus der Analyse stehen Formen der Kombination von CIB&S; Wirkungen auf Nachvollziehbarkeit und Konsistenz sowie weitere (nicht-intendierte) Folgen der Verwendung von CIB innerhalb solcher Kombinationen, und schließlich diejenigen Faktoren, die diese Wirkungen beeinflussen.

Kombinierte Szenario-Ansätze werden in dieser Studie als inter- und transdisziplinäre Methodologien konzeptualisiert, die in ihrer praktischen Anwendung jeweils eine individuelle soziale, technische und datenbezogene Organisation aufweisen. Aus dem Forschungsstand zu kombinierten Szenarien werden zentrale Dimensionen zur Charakterisierung unterschiedlicher Formen von Kombinationen von

qualitativen und quantitativen Szenariomethoden abgeleitet. Außerdem wird ein Modell für die typischen Phasen eines CIB&S-Prozesses entwickelt. Zur Bewertung von Wirkungen werden Arbeitsdefinitionen von Szenario-Nachvollziehbarkeit und Szenario-Konsistenz entworfen und operationalisiert.

Dieser konzeptuelle Rahmen strukturiert die empirische Analyse von zwei explorativen Fallstudien. Der erste Fall untersucht eine Methodendemonstration für das Umweltbundesamt (UBA). In diesem wird CIB eingesetzt, um die (gesellschaftlichen) Rahmenannahmen von Umweltmodellen zu analysieren und in sich stimmige Annahmenbündel bis zum Jahr 2030 zu konstruieren. Der zweite Fall ist eine vollständige Pionieranwendung von CIB&S im Rahmen eines Megacityprojektes für das Bundesministerium für Bildung und Forschung (BMBF). In diesem wird CIB mit einem Stoffstromsimulator kombiniert, um integrierte Szenarien über mögliche Wasserzukünfte von Lima, Peru, bis zum Jahr 2040 zu erstellen. Beide Fälle werden auf Basis von teilnehmender Beobachtung, Interviews mit Prozessbeteiligen sowie Prozessdokumenten qualitativ analysiert und interpretiert.

Die Studie zeigt, dass CIB in verschiedenen (idealtypischen) Formen der Kombination mit numerischer Modellierung und Simulation verschiedene Funktionen übernimmt. Die Form der Kombination wird dabei vor allem durch die Position beider Komponenten sowie durch den Grad ihrer Integration bestimmt. CIB&S-Ansätzen kann es dabei gelingen, die Szenario-Nachvollziehbarkeit zu unterstützen, sowie zur inneren Konsistenz der qualitativen Szenario-Komponenten und zur Konsistenz zwischen qualitativen und quantitativen Szenario-Komponenten beizutragen. Je stärker der Grad der Integration zwischen CIB und Simulation, desto stärker sind diese Wirkungen. Integration setzt jedoch voraus, dass die den Szenarien zugrundeliegenden Modelle, d.h. sowohl das konzeptuelle CIB Modell als auch die numerische Modellierung und Simulation, explizit und zugänglich gemacht, miteinander verglichen und gegebenenfalls aneinander angepasst werden. Weiterhin können CIB&S-Ansätze die ‚Checks and Balances' innerhalb kombinierter Szenario-Methodologien verändern, wenn die Definition von Szenarien sowie die Auswahl von Szenario-Samples an die CIB und ihre Beteiligten übertragen werden. Zur Erstellung von explizit normativen sowie von partizipativen Szenarien erscheinen CIB&S-Ansätze weniger geeignet. Stattdessen unterstützen CIB&S-Ansätze die teilnehmenden Experten dabei, ihr Wissen, ihre Annahmen und ihre Ideen zu möglichen zukünftigen Entwicklungen von interdependenten Mensch-Umwelt-Systemen besser zu analysieren, zu strukturieren und zu reflektieren. Die externen Nutzer von CIB&S-basierten Szenarien können davon profitieren, dass die Annahmen über Unsicherheit und Komplexität, die hinter den qualitativen und quantitativen bzw. integrierten Szenarien liegen, besser zugänglich und damit überhaupt diskutier- und kritisierbar werden.

Insgesamt geht diese Studie einen Schritt in Richtung einer stärker konzeptuell fundierten und reflektierenden Forschung zur Vielfalt möglicher Varianten kombinierter und integrierter Szenario-Methodologien.

Readers' guide

Throughout this study, direct quotations from literature are marked by double quotation marks. Single quotation marks are used to introduce special terminology. For emphasis, *italic type* is used. Original statements by interviewees al well as quotations from field notes (henceforth referred to as FN) are marked in *"type size 10, italic, double quotation marks."* Quotations from process documents (henceforth referred to as DOC) are marked in "type size 10, double quotation marks." References to interviews, field notes and process documents indicate the number of the quoted paragraph, unless otherwise stated. *In chapter 6, aspects concerning a hypothetical form of scenario methodologoy are marked in grey and italic type.* In text with italic type, for emphasis, words are underlined.

To better protect the anonymity of the case participants, they are all referred to using the masculine form, even if gender was equally distributed across all actor groups of both cases.

Figures, tables and translations are my own unless otherwise indicated.

Websites and internet sources referred to within the text are not listed within the references, but are documented in the form of footnotes. For all internet sources, the last visited date is January 12, 2016.

Chapter 1: Constructing better scenarios[1]

1.1 Searching for traceable and consistent socio-environmental scenarios

1.1.1 Using combined scenario methodologies to construct socio-environmental scenarios

It is December 2015, when the world's leading politicians are meeting in Paris for a UN climate change conference with the "aim of achieving a legally binding and universal agreement on climate, with the aim of keeping global warming below 2°C."[2] Global warming is recognized as being driven by our human activities and has and will have important effects on the future of our planet. Climate change impacts our natural living conditions, for instance in terms of biodiversity, sea level rise, changing patterns of precipitation causing flooding and drought. In turn, these changes also impact the future or our societies, regarding in particular, but not limited to, social inequalities, conflicts, migration and well-being. Future co-development of our environment and of our societies, including their future international organization and the policies in place, are uncertain. To a large degree, the interaction between and feedback from future social, political, economic, cultural and environmental developments are complex. Therefore, future climate change and its effects can only be predicted to a certain extent. Nevertheless, today's actions—or inactions—have long-term consequences.

To support informed decision making under this type of future uncertainty and complexity (cf. van Asselt 2000), the *scenario* approach was developed in the field of futures studies. The climate conferences for example, are informed by the so-called 2°C scenario, published by the Intergovernmental Panel on Climate Change (IPCC). It anticipates that if global average temperature rises beyond this 2°C-level, up to, for instance, 4°C, this will have dramatic impacts on our living conditions and social worlds. Scenarios are pictures of possible futures, often comprising the pathways leading to these (cf. e. g. von Reibnitz 1991, Gausemeier/ Fink/ Schlake 1996, Steinmüller 2002). Scenarios are used to transform future openness and complexity into a set of distinct, internally coherent alternative outlines of what might be (cf. also Grunwald 2002). In contrast to prognosis and predictions, which claim to provide information on alternative future presents ("zukünftige Gegenwarten" Grunwald 2011), scenarios are tools to reflect the knowledge, ideas and expectations we have *today* with regard to the future ("gegenwärtige Zukünfte" ibid.).

1 This PhD thesis is based on the research project ACCESS "Analyzing social context complexity of environmental simulations" funded by the German Research Foundation (DFG) within the Cluster of Excellence in Simulation Technology (EXC 310/2) at the University of Stuttgart.

2 Source: URL:http://www.cop21paris.org/about/cop21

Scenarios have multiple functions (cf. e. g. Greeuw et al. 2000, Alcamo/ Henrichs 2008, Kosow/ Gaßner 2008). *Exploratory* scenarios are developed to explore what might occur. These scenarios serve to increase our inter- and transdisciplinary system understanding. *Normative* scenarios are developed to deliberate about how we want our futures to be or not to be. Both types of scenarios are used to raise awareness and to communicate as well as to plan and to develop robust strategies; strategies of what we need to do now to get where we want to be—or to avoid futures perceived as undesirable. Finally, scenarios are applied to sharpen and to reflect our present knowledge as well as currently existing normative visions of our futures. In sum, scenarios have multiple descriptive-analytical, creative-normative, synthetic and communicative purposes.

Scenarios are produced and used in various fields, such as business, politics, education as well as science and research (cf. Tourki/ Keisler/ Linkov 2013). Accounting for their multiple purposes, a multitude of scenario methods and techniques was developed. Roughly, scenario methods comprise so-called qualitative, quantitative and integrated approaches. *Qualitative* approaches cover a broad range from intuitive-creative to systematic-formalized techniques. *Quantitative* approaches comprise numerical techniques of all sorts including modeling and simulation. Finally both types of approaches are combined or integrated into qualitative-quantitative approaches. These integrated scenario approaches are applied to deal with socio-environmental, socio-technological or socio-economic futures, for example. All three types of approaches structure scenario construction processes in specific ways and impact the resulting scenarios. They result in text, i.e. in more or less narrative storylines, or pictures, movies etc.; or in numerical information, i.e. in numbers, graphs; or in forms of combined or integrated textual, visual and numerical scenario presentations.

Typologies of scenario approaches basically distinguish between exploratory and explicitly normative scenarios (cf. e. g. Greeuw et al. 2000). But beyond this analytical distinction, exploratory scenarios are not free of normative elements (cf. e. g. Greeuw et al. 2000) and explicitly normative scenarios also include descriptive elements anchored in shared knowledge on past, present, and future conditions. Furthermore, one can distinguish between *expert* approaches carried out by modelers, researchers and experts of all kinds and *participatory* approaches, including decision makers, stakeholders, and even laypeople (cf. van Notten et al. 2003).

Scenarios are not shaped by methods and techniques alone, rather, they are developed within often highly complex *methodologies* (as in Hinkel 2008), that is specific constellations of *methods*, techniques and tools; of *actors* as scenario service providers and clients, the “producer-user” and the “recipient user” (Pulver/VanDeveer 2009); *data* in the widest sense, that is information, knowledge, ideas, hopes, fears, expectations as well as assessments and beliefs. In short, each scenario exercise is an individual and unique (idiosyncratic) exercise structured not only by methods but by many other elements. Together they result in “muddling through” activities (cf. van Asselt et al 2010) combining very heterogeneous “ingredients” (cf. Grunwald 2011). To underline the constructed character of scenarios, and because this study focuses on the production side, it uses the term ‘scenario construction’ instead of the perhaps more commonly used ‘scenario development’, ‘analysis’ or ‘planning’.

Scenarios have become especially important in inter- and transdisciplinary environmental research and sustainability sciences (cf. Swart/ Raskin/ Robinson 2004, Tourki/ Keisler/ Linkov 2013). In these fields, environmental sciences meet social sciences and futures studies. Scenarios of future developments of socio-environmental systems are mainly developed under the labels of ‘future environmental change’, ‘global change’ (e. g. Parsons 2008), ‘environmental scenarios’ (Alcamo 2008; Mahmoud et al. 2009) or scenarios of ‘coupled human and natural systems’. Typically, these scenarios consider mid- to long-term futures, meaning 20 to 50, and sometimes even more years into the future. They have a thematic scope on coupled social, technological and environmental systems dealing with issues such as climate change, biodiversity, land use, water management, natural resources and energy.

Classically, future scenarios of environmental systems are developed through numerical systems modeling. This provides decision makers with numerical information that is based on scientific methods. In these approaches, societal contexts are classically represented by a few quantifiable model inputs such as GDP (gross domestic product) or population growth and some model assumptions on technological change. Further, more qualitative assumptions on future societal development, like the change—or rather the stability—of values or lifestyles, social acceptance or policy preferences, lie outside the systems model’s scope and remain rather implicit. The same holds for (economic) beliefs and worldviews underlying these assumptions. At the same time, these—explicit and implicit—assumptions on societal contexts drive the model and often have an important impact on model results. Classically, modelers select this societal input data in internal and intuitive decision processes, often with reference to the same sources, such as the OECD or the United Nations, and then carry out sensitivity analyses for individual parameters. This classical approach does not adequately reveal (implicit) assumptions on societal futures, nor does it represent the uncertainty (or range) of possible future societal development and their complexity. Assumptions on different social developments are usually interrelated, and thus cannot be completely freely combined when logical contradictions and inconsistencies should be avoided.

In sum, the ‘modeling only’ practice becomes problematic, when societal aspects are not considered at the margins only, but when scenarios intend to adequately represent uncertain and complex futures of coupled natural *and* social systems. Furthermore, the modeling practice becomes problematic, when model-based scenarios are used beyond mere scientific exercises and thought experiments, but are intended to inform public debate and policy making, too. In such cases, other approaches are required, in order to provide more interpretable and more usable information.

Facing these challenges, in the last 15 years combined scenario approaches have been state of the art, when it comes to developing exploratory scenarios of environmental change (cf. Swart/ Raskin/ Robinson 2004, Rounsevell/ Metzger 2010). These approaches combine qualitative scenario techniques with numerical simulation models. The most prominent approach was developed by Joseph Alcamo (2001, 2008) and labeled the Story and Simulation (SAS) approach—but combinations are also called "integrated scenarios" (e. g. Döll/ Krol 2002), "narratives and numbers" (e. g. Kemp-Benedict 2004), or "hybrid scenarios" (e. g. Winterscheid 2007). To be clear, these approaches not only combine text and numbers in their scenarios, they also combine qualitative and quantitative approaches, meaning the methods and techniques for the construction of such scenarios. Also, I consider that integrated is a rather ambitious label: Not every combined approach is automatically a (deeply) integrated one—nor necessarily strives for deep integration. Therefore, in this study, I distinguish between the two and use the term combined scenario approaches to name the entire field.[3]

Combined scenario approaches are hybrid with regard to several dimensions (cf. also Swart/ Raskin/ Robinson 2004, Kosow 2015).[4] This hybridity stems from several tensions that are inherent to scenarios and futures studies more generally, and these tensions become especially apparent in combined socio-environmental scenarios.

First, combined scenario approaches combine methods from very different realms and disciplines, ranging from mathematical modeling and informatics to the facilitation of creativity workshops. Thus, they combine approaches that are traditionally marked by a methodological divide. In addition, they are marked by an "epistemological divide" (Hageman et al. 2013) between the perspectives of those who, from a rather positivist stance, believe in quantitatively calculating the future and those who, from a more constructivist perspective, believe in qualitatively visioning and creating the future (cf. also Grunwald 2013).

Second, combined approaches bring together various forms of data, as knowledge, information, assessments, assumptions and beliefs concerning past, present and future developments (cf. Grunwald 2011). To provide relevant orientation and futures knowledge, they must be anchored in accepted problem definitions and knowledge pools *and* at the same time, knowledge gaps we have with regard to what might come must be filled with creative elements (cf. also Swart/ Raskin/ Robinson 2004, Kuuri/ Cuhls/ Steinmülller 2015) — and if not explicitly, then in the form of informed expert guesses, for example.

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3 For more details on how this study conceives the field of combined and integrated scenarios please see chapter 2.3.1.

4 For comparably hybrid constellations, see attempts to combine agent based modeling and ethnographic research (Yang/ Gilbert 2007).

Third, combined scenario approaches include different types of *actors*, such as researchers, experts and stakeholders—and are at the same time targeted at decision makers, mainly in politics (cf. Alcamo 2008). Mostly, these decision makers do not have the resources to be fully included in these exercises but are mere recipient users of combined scenarios constructed by others. This constellation is challenging for scenario ownership, credibility, legitimacy, trust, and usefulness.

Fourth, combined scenario methodologies have hybrid purposes and are confronted with a multitude of expectations at the same time. Scenario exercises, when comprising modeling, have considerable academic and even scientific shares: They include researchers from the hard sciences, meaning natural sciences and engineering, in the scenario construction and result in scenarios that are published and assessed by academic criteria and further used in research contexts. They are expected to provide the best available knowledge and orientation—facing the uncertainty and openness of our futures. Thus, academic quality and analytical rigor are called for (cf. Kuuri/Cuhls/Steinmüller 2015). At the same time, combined and integrated scenarios are intended (and expected) to serve policy advice for making decisions. Their fundamental raison d'être is to be usable and relevant to policy making.

Fifth, such approaches also result in hybrid scenario products, comprising qualitative pictures of possible futures, visions, or storylines as well as quantitative model calculations.

In sum, combined scenario approaches have to bridge methodological and epistemological gaps. They need to cope with several tensions arising from their hybrid constitution, because they have multiple scientific and practical purposes and users, because they need to balance knowledge and creativity, and because they are assessed from different perspectives by different criteria.

The best documented SAS has a specific approach to combined scenarios (Alcamo 2001, 2008). Its basic idea is to construct a set of qualitative storylines covering a range of possible futures, to then translate the driving forces of the storylines into quantitative sets of input data for the numerical model(s), and to use these sets for scenario simulation. The approach relies on the principle of iteration. In other words, it recommends revising the storylines after simulation, adapting the input data sets to the refined storylines and repeating the simulation. The resulting scenarios comprise qualitative context descriptions and quantitative model calculations of the consequences of the system. SAS-type approaches have been applied to multiple fields, such as water management (Gallopin/ Rijsberman 2000, Döll/ Krol 2002), biodiversity (Carpenter et al. 2005), sustainability (UNEP 2007), land use (EEA 2007b, Kok/ Van Delden 2009), and its perhaps best known application in the field of climate change research, documented in the IPCC SRES report (Nakicenovic et al. 2000). Central benefits of SAS-type approaches, compared with the modeling only practice, are that qualitative factors are included (cf. also Alcamo 2008, Weimer-Jehle/ Kosow 2011, Kosow 2011, Weimer-Jehle/

Prehofer/ Vögele 2013, Weimer-Jehle et al. 2016); assumptions on future (social) developments behind model input are made explicit and uncertainty of social developments is addressed through alternative comprehensive storylines.

This thesis deals with one of the core approaches of futures studies, namely scenarios. Generally speaking, this approach deals with methods and methodologies that aim to construct 'good' scenarios. It focuses on combined and integrated qualitative-quantitative scenario approaches that are applied to explore futures of socio-environmental systems. Thus, this study does not focus on combined scenario methodologies with primarily explicitly normative or participatory aims. Instead, it focuses on scenario approaches with descriptive-analytical aims, which are used by applied (futures) research and future-oriented environmental research. I am aware that, due to their model-based origin, these approaches have a clear bias towards the academic side of futures studies and are therefore potentially threatened by positivist as well as technocrat tendencies. At the same time, exploratory and expert-based prospective analyses are and remain important as policy information tools, as research on the reception and impact of foresight has shown (cf. Havas/ Schartinger/ Weber 2010). This study focuses on the construction of these scenarios. In the following, the focus of this thesis is further sharpened and justified.

1.1.2 Relevance of searching for new forms of combined scenario methodologies — combining CIB with simulation

This study is motivated by five research gaps that are briefly introduced.

First, and this is of academic and practical relevance, the field of combined scenario approaches is conceptually underexplored. The field is rather broad and fuzzy, and there is little methodological guidance for those, who want to design and realize their own integrated and combined scenario processes. At the same time, the field is dominated by the so-called SAS approach. SAS itself was claimed to be a framework comprising different combined designs (Alcamo 2008). However, it is not a *systematic* or *conceptual* framework, providing a comprehensive overview of different forms in which qualitative and quantitative scenario approaches can be combined. It rather is an umbrella term that was, ex post, created to promote a specific type of empirical approach (cf. Alcamo 2001/ 2008). For instance, Trutnevyte together with colleagues (e. g. 2011, 2012), showed for the field of energy scenarios that further types of combinations are of course possible, going beyond the SAS type. However, individual strands developing new combined methods are not conceptually reflecting nor systematically embedding their approaches. Open questions are, e. g., what role can and should the two components play with regard to each other and for the overall scenario process? What type and degree of integration is possible and required, with what aims, and by what means? Furthermore, combined scenarios require complex forms of cooperation between actors from different cultures such as modelers, futurists and experts from various domains, and aim to integrate very different forms of knowledge (cf. Volkery et al. 2008). How can the social, cognitive and technical integration (cf. Becker et al. 2000) of these scenario methodologies be supported through their design?

Furthermore, the field of combined scenario methodologies is dominated by an approach that, despite its appeal, is fraught with difficulties. One of the key limits and challenges of SAS-type approaches—and this is the second research gap motivating this study—is their challenge of *traceability*. First, storylines suffer from a lack of *transparency,* as they are based on “assumptions and mental models of storyline writers [that] remain unstated” (Alcamo 2008). Second, model-based scenarios and especially their underlying assumptions are neither accessible nor transparent for non-modelers either. Traceability of scenario assumptions and construction is seen as an important substitute for participation during scenario construction exercises (Parson 2008, Grunwald 2011). Moreover, making assumptions on future developments and their interrelation explicit *and* making methods of scenario construction and sampling accessible are prerequisites when it comes to allowing external recipient users to assess the quality of scenarios, and to decide in an informed way whether and how to use these.

Another challenge of SAS—and this is the third research gap motivating this study—is related to issues of *consistency*. Generally, the SAS approach suggests that modeling and simulation are used to identify inconsistencies in the storylines (cf. Alcamo 2008 and others). But this consistency check is limited to those parts of the storylines that are also covered by the numerical systems model (cf. Schweizer/ Kriegler 2012). Furthermore, there are empirical hints that the promise of consistency by SAS is difficult to fulfill in practice. (cf. Volkery et al. 2008, Schweizer/ Kriegler 2012). Striving for consistency can be understood as an attempt to strive for academic rigor, to counter the supposed arbitrariness of scenarios, which in turn is linked to the fundamental openness of the future.

Overall, the issues of both traceability and consistency do show that the quality of SAS-type approaches[5] has room for improvement. This improvement seems advisable from an academic standpoint but has practical relevance, too. Schomberg, Pereira and Funtovicz argue that policy makers as recipient-users assess the quality of foresight knowledge in part as a function of its “scientific set up” (Schomberg/ Pereira/ Funtovitcz 2006: 168). They point out that for recipient-users, the quality of futures knowledge depends, inter alia, upon accessibility, availability, intelligibility and transparency of information as well as upon the adequate justification of assumptions and methods (ibid.). In sum, the highest possible academic quality of combined scenarios can contribute to their perceived credibility, legitimacy and usefulness for policy advice.

5 I use the term ’SAS-type approach’ for the mainstream type of combined scenario approaches used in the field of environmental scenarios.

Fourth, there is the ongoing debate in futures studies on standards and quality criteria.[6] Facing the mixture of scientific and policy applications of and expectations for socio-environmental systems scenarios, questions arise as to the assessment of whether, in what cases, and with what aims a scenario approach can be defined as a good approach, and how to choose from the possibility of different designs and forms of combined scenario methodologies. These questions are relevant to the scenario practitioner, who needs to make design decisions and also for the 'recipient-user', who is confronted with readymade scenarios without having experienced their construction. The scenario literature does not yet sufficiently answer the question of how to decide what good (integrated) scenarios and appropriate scenario approaches are. In current material written by scenario practitioners there seems to be an agreement that the quality of scenario approaches can be judged only in relation to the aim and function at stake and not absolutely.[7] Even if lists of quality criteria by different authors have been circulating for decades (cf. e. g. Heinecke/ Schwager 1995, Wilson 1998, Greeuw et al. 2000), criteria often are—if at all—only poorly defined and operationalized; different understandings are covered by apparent consensus (cf. e. g. van Asselt et al. 2010), or they are openly contested (cf. e. g. O'Mahony 2014). Different schools of scenario construction seem to have different criteria as a function of the priority they give to policy relevance (e. g. Cash et al 2003), to esthetics and creativity (e. g. Gaßner 1992, Gaßner/ Steinmüller 2006) or to scientific requirements.

Fifth, in the field of climate change, a critical discussion of the SAS-type approach is ongoing, and ways to take it forward are being developed.[8] In response to the perceived weakness of the storyline part (e. g. Garb et al. 2008), one strand of the discussion recommends the use of more *systematic and formalized* approaches when constructing storylines (e. g. Girod et al. 2009, Rounsevell/ Metzger 2010, Kemp-Benedict 2012), meaning approaches that go beyond the typical 'intuitive logics' (IL) technique (cf. Wack 1985a, 1985b). Currently, for the purpose of "telling better stories" (Kemp-Benedict 2012), cross-impact balance analysis (CIB) by Weimer-Jehle (2006) was proposed by several authors as just such a potential alternative or complement for developing the qualitative part of combined scenarios (cf. Kosow 2011, Schweizer/ Kriegler 2012, Kemp-Benedict 2012, Weimer-Jehle/ Prehofer / Vögele 2013, Weimer-Jehle et al. 2016).

CIB is a systematic yet qualitative form of systems analysis.[9] It shares with other forms of systematic-formalized scenario approaches that systems are characterized through qualitatively defined ele-

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6 Recent book publications (e. g. Gerhold et al. 2015) and conference themes hint at this debate. For example, the program of the World Conference of Futures Research 2015 suggested differentiating between criteria from a scientific, a practical and an educational perspective URL: https://futuresconference2015.wordpress.com.

7 See for instance URL:http://www.foresight-platform.eu/community/forlearn/how-to-do-foresight/.

8 The following paragraph draws from the section written by me in Weimer-Jehle et al. (forthcoming) titled: "Learning from other fields."

9 The following paragraph draws from Kosow 2015, and refers to Weimer-Jehle 2006, Weimer-Jehle 2014.

ments displayed in the form of a matrix. The CIB analysis more specifically constructs an impact network on future (societal) developments, i.e. a form of conceptual model. This impact network is based on expert judgments on the direction and strength of influences between alternative developments of system elements. System elements and their alternative developments are considered in their double role as influencing factors and as factors undergoing influence. Impacts are assessed pairwise by using a semi-formalized scale (from strongly hindering to strongly promoting impacts). These assessments are underpinned with textual justifications. The assumptions stored in the CIB matrix make explicit the mental model(s) of those who use the method. The specific methodic core of CIB is a form of balance analysis. It serves to identify internally consistent network configurations, meaning raw CIB scenarios. The balance analysis is based on the information on the impact relations between the alternative developments of system elements. Constellations are defined as internally consistent when they are in accordance with the impact arguments of the impact network. This function of CIB can be used to support the construction and selection of qualitative scenarios.

The recent proposal to use CIB in combination with simulation was labeled 'CIB and simulation' (Kosow 2011) or 'context scenarios' (Weimer-Jehle/ Kosow 2011, Weimer-Jehle/ Prehofer/ Vögele 2012, Weimer-Jehle et al. 2016). For instance, it was proposed to use CIB for constructing global socio-economic pathways for climate change research (Schweizer/ O'Neill 2014) within the new IPCC framework of shared socioeconomic pathways (SSP) (O'Neill et al. 2014). Overall, due to the specific characteristics of CIB, this new approach is expected to enhance combined scenario methodologies, especially as concerns their difficulties when it comes to traceability and consistency.[10] Still, the application of CIB *in combination with modeling and simulation has* neither been conceptually grounded nor empirically explored in a systematic way yet.

In sum, this study touches upon a field with a multitude of open questions. To provide orientation in a rather uncharted domain, it uses the difficulties of current combined scenario approaches to explore the possibilities of new forms. It focuses on new combined approaches of a specific type, namely exploratory forms combining systematic and formalized yet qualitative scenario approaches with simulation. More specifically, the issue of this study is the use of the qualitative systems analysis CIB together with numerical modeling and simulation (in the following, abbreviated as 'CIB&S'). The central motivation of the study is to explore, what actually happens, when CIB is used in combined scenario approaches; what functions CIB can fulfill; and what these combination look like. With regard to the expected beneficial effects of CIB on traceability and consistency, this study seeks to find out where the use of CIB helps—and where it does not help; and what effectively changes, compared

[10] CIB and the expectations linked to this approach are further described in chapters 3 and 4.

with SAS-type approaches, when this new approach is used. Finally, it aims at learning how CIB&S processes can be (most) effectively designed.

1.2 Research questions, approach and contribution

The initial research question of this study is:

(How) can the use of CIB within combined scenario methodologies support inter- and transdisciplinary research groups to construct qualitative *and* quantitative or integrated exploratory scenarios of socio-environmental systems?

In principle, thinking CIB and combined scenario approaches together opens a broad field of possibilities of using CIB within these combined approaches. The literature review shows that little guidance is available regarding combined scenario approaches beyond those of the SAS-type. Therefore, this study uses the SAS framework as a starting point to conceptualize new forms of combined scenario methodologies, using combinations of CIB with modeling and simulation (forms of CIB&S). This decision narrows the focus of this study, focusing mainly on combinations of CIB with numerical simulation models (type CIB&S). This permits the study to deal with a manageable topic in the necessary depth. But we keep at the back of our minds that the field of combined scenario approaches is larger and more diverse than what is proposed under the SAS umbrella.[11]

In the course of the study, the initial research question is further specified into the following three questions.

1. In what *forms* can CIB be combined with numerical simulation models to support interdisciplinary research groups to construct qualitative *and* quantitative or integrated scenarios of socio-environmental systems? (*forms of CIB&S*)
2. What *effects* does the use of CIB in combination with simulation models have on scenario traceability and scenario consistency? What are other (unintended) effects? (*effects of CIB&S*)
3. How are these outcomes of the use of CIB influenced by *other factors*, namely by the characteristics of the scenario methodology and by the form of CIB&S? (*influencing factors*)

To answer these questions, I explore the use of CIB within combined scenario methodologies conceptually and empirically. This leads to two contributions to futures research and future oriented environmental research, namely a conceptual and an empirical one.

[11] This focus is further justified in chapter 2. The consequences linked to this choice are discussed in chapter 8. There, I also attempt to look beyond this frame(work), sketching the use of CIB within combined scenario methodologies more broadly.

Based on a review of the literature addressing combined scenario approaches and CIB, I have recently developed a pragmatic *conceptual* framework on CIB&S methodologies. This framework proposes to differentiate between different forms of CIB&S approaches through a small set of dimensions. Furthermore, it provides an ideal process model specifically tailored to describe typical phases of a CIB&S process and the different scenario products resulting from such a process. To allow the assessment of the effects of CIB&S methodologies, the framework proposes working definitions and operationalization of scenario traceability and scenario consistency and characterizes different types of effects. The framework thus supports a form of method(ology) assessment of CIB within combined scenario methodologies: It enables the search for the expected and unintended effects of CIB on combined scenario processes and scenarios vs. the effects of other elements of these scenario methodologies, namely the interplay of actors, methods and data, in the broadest sense. In this study, the conceptual framework is empirically applied to two case studies; it is then reflected and discussed with regard to its usability and transferability and is finally further refined.

The conceptual framework on CIB&S was used to structure the *empirical* exploration of two specific CIB&S methodologies in the form of exploratory case studies (Yin 2009). In both cases, CIB is combined with numerical simulation models to construct socio-environmental scenarios within inter- and transdisciplinary research projects.

- Case I, in the following called the *UBA case*, is a first demonstrator application of CIB&S. The UBA case is based on the research project 'Consistent framework assumptions informing model- and scenario-analysis at the German Federal Environment Agency (UBA).' In this case, CIB is used in the role of an analyst and provider of societal input data sets ('Germany 2030') for a group of environmental models.
- Case II, in the following called the *Lima Water case,* is a full pioneer application of CIB&S. It is based on the research project, "Sustainable water and wastewater management in urban growth centers coping with climate change, concepts for metropolitan Lima (Perú)" (LiWa). CIB is used to steer a combined scenario process leading to integrated scenarios of Lima's water futures in the year 2040, combining qualitative descriptions and numerical information from simulation inputs and outputs.

The two unique cases, a demonstrator and a pioneer application of CIB&S, have been chosen because they were, at the time when this study began, the only ongoing (and accessible) CIB&S cases.[12] Both cases can be considered *typical* cases with regard to their aim and their form, in which CIB is combined with simulation: The UBA case represents the use of CIB&S to harmonize societal input

[12] Meanwhile, further applications are ongoing, see Weimer-Jehle et al., Prehofer et al., both forthcoming.

assumptions of model groups; the Lima Water case represents the use of CIB&S to construct integrated scenarios.

I attempt to take over the research perspective of a *reflective foresight practitioner* (cf. van't Klooster/van Asselt 2006, van Asselt et al. 2010).[13] I had access to both cases in the role of a research team member and was, albeit to different degrees, involved in the design and implementation of both methodologies in the role of a 'CIB scenario expert'. I am using this insider perspective to gain insight into this specific new scenario practice, to take a step back to reflect and conceptualize these, using the results to inform scenario practice. To support a conscious and systematic reflection within this thesis, additional evidence on both cases was collected and analyzed. This evidence allows the (perceived) traceability of the scenario construction processes to be assessed, mainly based on the analysis of interviews with process participants and on participant observation. Furthermore, it allows the consistency of scenario products to be assessed, mainly based on content analysis of process documents. The detailed analysis of the methodologies—individually for each case—makes it possible to plausibly interpret their internal dynamics and to trace the respective degrees of traceability and consistency of each case back to CIB and/or to effects of further factors in the methodologies. Then, overall, and across cases, the insights are synthesized as follows.

- On the different *functions* of CIB in different (ideal type) *forms* of its combinations with numerical simulation models in combined and integrated scenario methodologies.
- On first and second order effects of the use of CIB within combined scenario methodologies on scenario traceability, scenario consistency and further phenomena, namely on the checks and balances within and the effort, flexibility and creativity of combined scenario methodologies.
- On *factors* influencing these effects, namely the social organization, technical design and data-related characteristics of the methodology as well as the form of combination, especially with regard to the position (CIB first vs. model(s) first) and the degree of integration between both (high vs. low).

The recommendations that can be deduced from these insights can orient future research in designing and applying combined and integrated scenario methodologies using CIB. Learning from this specific new approach also allows generalizing insights relevant for the entire field of combined and integrated scenario methodologies.

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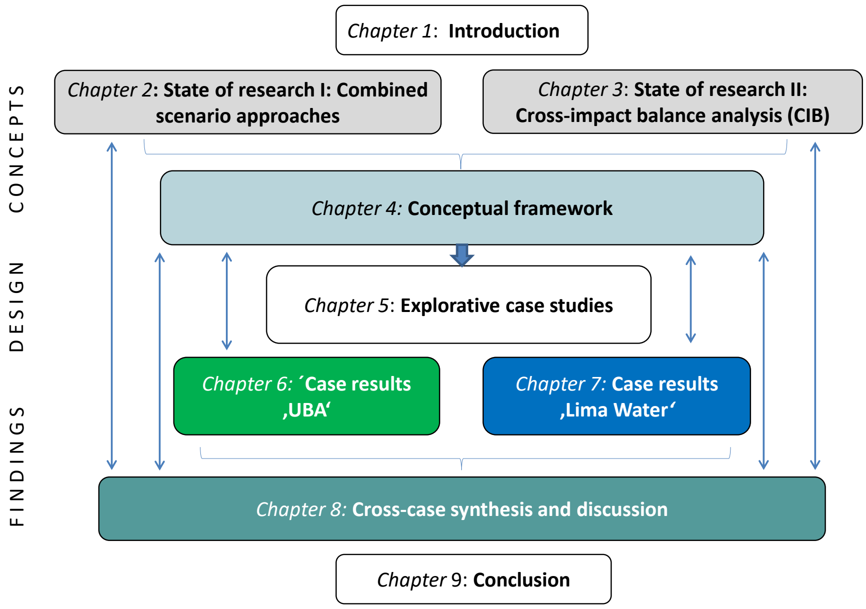
13 With reference to Schön's book "The Reflective Practitioner" (1983), see chapter 5 of this study.

1.3 Structure

Figure 1 gives an overview of the structure of this thesis.

Figure 1: Overview of the structure of the thesis



In a first step (chapter 2), against the general contexts of futures studies and scenario approaches, the state of research on the ideas in and practice of combined scenario approaches is established. A review of the empirical variety of combined scenario approaches serves to learn about the typical forms of the combination of qualitative scenario methods with simulation as well as the typical phases of combined scenario construction processes. Research gaps with regard to the current practice of combined scenario construction are identified, showing that issues of scenario traceability and consistency are central threats to the quality of the combined scenario approaches of the SAS type.

Then, (chapter 3) the state of research on CIB as a qualitative form of systems analysis and qualitative technique is established and the current proposal to combine CIB with simulation is detailed. Furthermore, I give an overview of empirical experiences with CIB and then specify what properties of CIB are expected to improve combined scenario approaches with regard to given dimensions of scenario traceability and consistency.

Based on the state of research, a conceptual framework is developed to support the analysis of scenario methodologies, combining CIB with simulations and, more specifically, to make it possible to search for the effects of CIB within combined scenario methodologies (chapter 4). Its basis is the understanding of (combined) CIB&S scenario approaches as (idiosyncratic) inter- and transdisciplinary scenario methodologies. Further conceptual elements on CIB&S methodologies, processes and products are added, derived from the analysis of the current practice of SAS. In addition, working definitions of scenario traceability and scenario consistency are proposed as central assessment criteria used in this study. The research question is further refined for the empirical analysis and expectations with respect to effects of CIB&S on scenario traceability and consistency are made explicit.

Then, the research perspective of this study and the use of case study research are explained and the empirical design of two exploratory case studies is described (chapter 5). The UBA case permits an in-depth analysis of the effects of CIB on the construction of societal input data sets for a group of models. The Lima Water case permits an in-depth analysis of the effects of CIB throughout a full combined scenario process resulting in integrated scenarios. Case study data was collected by participant observation, interviews with process participants and collection of process documents. The individual cases are analyzed by means of qualitative data analysis and content analysis; results are reviewed and cross-checked by key informants. Then cases are compared across cases to synthesize generalizing insights. This is supported by validation through experts and practitioners. Finally, the quality of the design and the data, as well as the validity of the findings is discussed.

Central results from both case studies are presented individually, case by case. First, central results from the demonstrator application of CIB&S in the UBA case (chapter 6) are described and then interpreted. This chapter focuses on the effects of CIB on the construction of societal input data sets for a model group. Then, central results from the pioneer application of CIB&S in the Lima Water case (chapter 7) are described and interpreted. This chapter focuses on the first- and second-order effects of CIB throughout a full combined scenario process, which results in integrated systems scenarios.

Based on a comparison of the individual case results, cross-case results are discussed and mirrored against the initial expectations (chapter 8). To answer the research questions of this study, overall results are synthesized in the form of insights into functions of CIB in different ideal forms of its combination with simulation models; on the effects of CIB on scenario traceability and scenario consistency and on other (unintended) effects; and on factors influencing these, namely characteristics of the methodology and the form of combination. Then, the conceptual framework is discussed, refined and in part transferred. Finally, my findings are confronted with the state of research on CIB and on combined scenario methodologies, considering SAS-type and other approaches; and the place of CIB&S in futures studies is precisely defined.

To conclude, the approach of this study and its central findings are summarized; the limits and avenues of further research are indicated (chapter 9).

Chapter 2: State of research I: Combined scenario approaches

In this chapter, I sum up the state of research on combined scenario approaches. As the state of research is spread over various fields, this chapter is based on a literature review and supported by open and exploratory expert interviews (cf. Bogner/ Littig/ Mentz 2005) with scenario experts and modelers;[14] and through the use of European compendia on scenario studies.[15]

This summary focuses on scenario approaches combining qualitative scenario techniques with model- and simulation-based techniques. To be clear, this chapter is not primarily about 'qualitative-quantitative scenarios', meaning scenarios as *products* mixing numbers and text.[16] Instead, it deals with the *approaches*, meaning the *methods* and *techniques* used for the construction of such scenarios. Furthermore, this chapter focuses on scenario techniques mainly used in the field of socio-environmental systems analysis and asks: What do we know about the use of combined scenario approaches to construct socio-environmental scenarios? Where do these approaches come from, what are their benefits, what are their limitations? I briefly describe scenarios as the central technique of futures studies, a field in tension between practical and academic expectations (2.1). Qualitative and quantitative scenario approaches are linked to quite different traditions and paradigms (2.2). Combined scenario approaches are the state of the art in environmental scenario studies, mainly in the form of the SAS approach (2.3). Despite having plenty of appeal, this hybrid approach is also fraught with difficulties. Two main challenges of the combined scenario approaches of the SAS type are related to traceability issues and to their promise to ensure consistency between storylines and numerical scenarios (2.4.). Finally, I sum up central lessons and research gaps (2.5).

2.1 Futures studies

Scenarios are one of the core methods of the field of futures studies, an *inter*- and *transdisciplinary*, *participatory,* and explicitly *future oriented* field. (2.1.1). This field is characterized by tensions between scientific credibility and practical usefulness that are also reflected by current discussions on its quality (2.1.2).

14 Both scenario practice and environmental modeling are fields with important degrees of tacit knowledge that is not published in official papers and textbooks, and the literature relevant to my issue is spread across several communities. A list of the n= 11 experts interviewed in the USA and in Germany in 2010 can be found in Annex A.

15 An early overview and assessment was given by the European Environmental Agency (Greeuw et al. 2000). This was complemented by further EEA reports (EEA 2007a, 2009 and 2011).

16 It is current practice to add quantitative information to qualitative scenarios, if available—and model-based scenario results require some verbal description to make sense.

2.1.1 Characteristics of futures studies

Facing the uncertainty of future developments of societies, technologies and their natural environments and the complexity within and between each of these domains, futures studies, sometimes also labeled ‘foresight’, ‘forward looking activities’ or ‘futures research’ have been under development in the USA since the 1950s. Their development started with applications in the military (e. g. by RAND) and business (e. g. SHELL) and were then extended to policy advice as well as to technology and environmental research (e. g. Forrester 1971).[17] Since then, the field has developed various schools (cf. Bradfield et al. 2005; Amer/ Daim/ Jetter 2013)[18] and has undergone important paradigm shifts.[19]

“The purposes of futures studies” as defined by Bell (1997: 73) “are to discover or invent, examine or evaluate and propose possible, probable and preferable futures” (ibid, cf. also Kreibich 2006). The ambitions of the more practice oriented *foresight*, as for instance currently defined by the European Union, are even larger[20] and consist in “thinking the future”, “debating the future” and “shaping the future”.[21] More currently, the label futures research was introduced to distinguish the academic side of the field (cf. Kuuri/ Cuhls/ Steinmüller 2015: 61).[22] In sum, the field stretches from corporate (strategic) foresight in business over rather academic futures research to forms of policy advice for governments.

Despite these differentiations in more practice oriented and more academic branches, and despite the different social systems that are (mainly) targeted (as economy, politics, academia), the underlying raison d’être of the entire field is to support present decisions and decision makers, that is those, who are in the role and responsibility to take decisions and action, with long term consequences – and to do so despite the uncertainty of our future (cf. e. g. van Asselt 2010).

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17 Neighboring approaches developed for similar purposes are, e. g., the fields of sustainability research and technology assessment (TA). For an overview of historical developments of futures studies especially in Germany, see e. g. Seefried 2014, Kreibich 2006.

18 The authors centrally distinguish between the intuitive logic school, the probabilistic modified trend school and the French school (la Prospective founded by Gaston Berger).

19 Centrally, these were the paradigm shifts from forecasting to foresight (see e. g. Cuhls 2003, Seefried 2014) away from planning and prediction optimism to the recognition of future contingency. The currently competing and changing labels might be a sign for ongoing shifts in the identity of the field. For a proposal to define these different labels, see Kuuri, Cuhls and Steinmüller (2015: 61).

20 “Foresight is a systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at enabling present-day decisions and mobilizing joint actions” URL: http://www.foresight-platform.eu/community/forlearn/what-is-foresight/.

21 URL: http://www.foresight-platform.eu/community/forlearn/what-is-foresight/. For a quite similar definition see e. g. the World Future Society (WFS):”research, envision and create potential futures”; URL: https://www.wfs.org/Upload/WFS_Org%20Overview_m4.pdf.

22 The EU currently proposes to distinguish between more academic ’futures studies’ and more action-oriented ‘foresight’; URL: http://www.foresight-platform.eu/community/forlearn/what-is-foresight/

There is a consensus that to support such decision making effectively, *interdisciplinary* and *participatory* approaches are required, approaches that bring together various actors, such as experts of all kinds, stakeholders and decision makers. Due to their inter- and transdisciplinary character, futures studies share the challenges and the approaches of other *applied, problem-oriented and inter- and transdisciplinary fields* (cf. e. g. Becker 2000 and Bergmann 2010). This more general phenomenon has also been analyzed under the labels of “post-normal science” (Funtowicz/ Ravetz 1993, Ravetz/ Funtowicz 1999) and “mode 2 knowledge production” (Gibbons et al. 1994; Nowotny et al. 2001).

The specificity of futures studies, then, is its explicit *future orientation*. Its basic assumption is the openness of the future, which is often emphasized by the use of the plural ‘futures’. Actors doing futures studies[23] assume that the future is neither completely predictable and calculable nor completely random or chaotic, but at least to a certain degree shapeable by our decisions.[24] *Scenarios* are the field’s core approach to transforming the openness of the future into a (small) set of distinct, alternative pictures of the future, including the dynamics leading to these scenarios (cf. section 2.2.).

Interdisciplinary *environmental research* (cf. e. g. Scholz/ Tietje 2002) is a neighboring field of futures studies, in which scenario approaches are used and also developed. At the same time, futures studies have been influenced by ideas on sustainable development originally developed in the field of environmental research.

In sum, futures studies, and their core approach scenarios, are always situated between research and practice. They constitute an inter- and transdisciplinary field that defines its raison d’être in providing support in dealing with the uncertainty of the future. But how to assess whether the support is good?

2.1.2 What are good futures studies?

Expectations of good futures studies are characterized by several tensions. Generally, there are tensions between academic and practical expectations. Some actors emphasize the practical usefulness as primary quality criteria.[25.] Others see themselves rather as scholars working in an (increasing institutionalized) academic discipline with a system of peer-reviewed journals,[26] conferences and univer-

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[23] These actors sometimes are summarized under the label ‘futurists’ (cf. e. g. Kuuri/Cuhls/Steinmüller 2015: 61).

[24] With regard to conceptions of the future, see e. g. Grunwald 2002, Kosow/ Gaßner 2008.

[25] This certainly has to do with the search for legitimization and concretely, funding. For instance, the EU currently proposes to distinguish between more academic ‚futures studies‘ and more ‚action oriented foresight (URL: http://www.foresight-platform.eu/community/forlearn/what-is-foresight/)

[26] With international peer-reviewed journals as, e. g., Futures (since 1968), Technological Forecasting and Social Change (since 1969), more currently Foresight (since 1999) and rather new European and German Journals: European Journal of Futures Research (since 2013) and Zeitschrift für Zukunftsforschung (since 2012).

sity posts, striving for academic standing and follow rather academic quality criteria.[27] In this position, futures studies are confronted with (and generate) multiple, and at times conflicting, expectations. More concretely, there is a tension between the expectations of “creative imagination” on the one hand and “fact based justifications” on the other hand (cf. Kuuri/ Cuhls/Steinmüller 2015: 60). Underlying this dynamic, there are tensions between different epistemological positions (cf. Hageman et al. 2013). Ethnographic research on foresight by van Asselt and colleagues (2010: 141) has shown that through the “academic ambition” in foresight, old rather *positivistic* ideals are (re-) introduced, which are in sharp contrast to the (necessary) *constructivist* position that is constitutive for a field concerned with future openness: “In foresight, positivistic ideals are active as results of the academic ambition.”

These tensions are reflected by the current quality discussions in the field, discussing standards and quality criteria. As different paradigms, traditions and methods from different disciplines, from academia and practice come together; different quality criteria meet and at times come into conflict.

Overall, there is no established consensus on quality criteria (cf. Tourki/Keisler/Linkov 2013 and Kuuri/ Cuhls/ Steinmüller 2015). Many of the criteria in use are defined only weakly and no consensual or shared understanding is given.[28] Often, criteria are imported from neighboring fields, e. g., criteria initially developed by Cash and colleagues (2003) for the field of sustainability research.[29] Potentially due to missing established alternatives, these are repeatedly applied to (environmental) scenarios[30]—but they are not specific to futures studies or scenarios.

Authors seem to agree that *procedural* standards and criteria are necessary when assessing the quality of futures studies, e. g. transparent and clear methodologies and understandable procedures (cf. e. g. Gerhold et al. 2015) or the rigorous application of principles (Asselt et al 2010: 145). Philosophers of science argue that scenarios cannot be judged as outputs but only by their ingredients (e. g. Grunwald 2011, Dieckhoff et al. 2014, cf. also Hulme/ Dessai 2008), and these ingredients need to be

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27 Also linked to the search of legitimization and concretely, funding.

28 See for instance the criteria of consistency, robustness (van Asselt et al. 2010: 59), and plausibility (Selin 2011).

29 Cash and colleagues argue for science and research becoming useful for sustainability, and in order for knowledge to be transferred into action, the information a knowledge system produces needs to be a) salient, b) credible, and c) legitimate. The authors argue that “scientific information is likely to be effective in influencing the evolution of social responses to public issues to the extent that the information is perceived by relevant stakeholders to be not only credible, but also salient and legitimate" […]"In the sense used here, credibility involves the scientific adequacy of the technical evidence and arguments.” “Salience deals with the relevance of the assessment to the needs of decision makers."; "Legitimacy reflects the perception that the production of information and technology was respectful of stakeholders’ divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests." "Our work shows these attributes are tightly coupled, such that efforts to enhance any one normally incur a cost to the others” (Cash et al. 2003: 8086).

30 See for instance Alcamo/ Henrichs 2008, Girod et al. 2009, Rounsevell/ Metzger 2010 and Kunseler et al.2013, albeit each with slightly diverging definitions.

revealed through a hermeneutic approach (Grunwald 2013a). For instance, Grunwald (2011, 2015) stresses that futures studies need to be evaluated with regard to two dimensions, the ingredients they use and their composition.[31] But there seems to be no consent on the question of the degree to which substantial criteria are appropriate.

Van Asselt and colleagues (2010) have shown that, in *practice*, there are many tensions between ideal typical textbook representations on the one hand and the effective "foresight in action" (the title of their book) on the other hand. First of all, activities are often "muddling through" activities, sometimes strongly based on the tacit and experiential knowledge of practitioners. In a negative definition, the authors qualify those activities as bad foresight that fall into "positivism," "certainification" and "historical determinism", that is those approaches that are oriented toward classical academic quality criteria (cf. van Asselt et al. 142-144).

The authors plead for a more reflective approach to foresight (cf. van Asselt et al 2010: 142 ff.):

> The reflexive practice of foresight could start by accounting for not only the different anticipated but also the unanticipated steps that were taken throughout the project in their publications. Or by acknowledging that formal rhetoric may not be sufficient to account for explaining how the mission actually was accomplished. (van't Klooster/ van Asselt 2006: 28)

The authors recommend that, instead of propagating myths, we should learn from each other to improve our "capacity to structure the unknown" (van't Klooster/ van Asselt 2006: 29).

Very recently, on the more academic side, that is in the field of futures research, a group of authors (Gerhold et al. 2015) presented a list of standards and criteria discerning between three groups of criteria, a first group that applies specifically to futures studies with their specific issue, namely 'the future', a second group that corresponds to criteria of good research practice also valid in other fields and a third group of criteria that focuses issues of relevance. Another recent paper by Kuuri, Cuhls andSteinmüller (2015) proposes to discern *internal* validity, which is mainly process- and method-related; and *external* validity, mainly fact- and theory-related, of what they call 'future maps', i.e. outcomes of futures research.[32]

In sum, the debate on the quality of futures studies and of their core approach, scenarios, is ongoing. Important questions remain concerning how to balance the—sometimes contradictory—expectations when it comes to their practical usefulness and their academic soundness.

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31 Furthermore, he proposes distinguishing between three different modes of orientation that futures studies seek to provide (Grunwald 2013a): mode 1, based on the paradigm of historical determinism, deducing logical and reliable consequences from past developments, e. g. in the form of numerical point predictions; mode 2, based on the paradigm of future openness providing 'diversity', e. g. in the form of a set of possible scenarios; and mode 3, based on the 'hermeneutics of the present' seeking to explain 'divergence' among present ideas on the future.

32 As these proposals were only available towards the very end of this study, at this point they had not yet influenced the development and application of my framework (chapter 4). Their relation to the criteria used in this study is discussed in section 8.4.3.

2.2 Qualitative and quantitative scenario approaches

To foreground the field of combined scenario approaches, I first give an overview of scenarios and scenario approaches (2.2.1).Then, and more specifically, I introduce the so-called qualitative (2.2.2) and quantitative scenario approaches (2.2.3).

2.2.1 Scenarios

Figure 2 gives an example of four alternative global scenarios on the future of sustainable development.

Figure 2: „A tale of four futures"- The GEO-4 scenarios up to 2050

My illustration based on UNEP 2007.

Markets First pays lip service to sustainable development in terms of the ideals of the Brundtland Commission, Agenda 21 and other major policy decisions. There is a narrow focus on the sustainability of markets rather than in the context of the broader human-environment system.

Policy First introduces some measures aimed at promoting sustainable development, but the tensions between environment and economic policies are biased towards social and economic considerations.

Security First focuses on the interests of a minority: rich, national and regional. It emphasizes sustainable development only in the context of maximizing access to and use of the environment by the powerful.

Sustainability First gives equal weight to environmental and socio-economic policies, accountability, and it stresses transparency and legitimacy across all actors. It emphasizes the development of effective public-private sector partnerships not only in the context of projects but in the area of governance, ensuring that stakeholders across the environment-development discourse spectrum provide strategic input to policy making and implementation.

Even if a multitude of scenario *definitions* (co-)exists,[33] most authors do agree that scenarios can be understood as pictures of alternative futures, including the pathways leading to these futures (cf. e. g. von Reibnitz 1991, Gausemeier/ Fink/ Schlake 1996, Steinmüller 2002). Whereas some definitions put more emphasis on the (static) pictures of possible futures (e. g. EEA 2009),[34] others instead stress the roads and pathways towards them (i.e. their dynamics) (e. g. Kahn/ Wiener 1967) and speak of storylines.[35] In contrast to prognosis and predictions, claiming to inform about alternative presents that might occur in the future—future presents ("zukünftige Gegenwarten")—scenarios are tools to reflect present futures: the ideas and expectations we have *today* with regard to the future ("gegenwärtige Zukünfte", cf. Grunwald 2011). Following the basic assumption of futures studies or

33 For an overview, see e. g. Mietzner/ Reger 2004, Kosow/ Gaßner 2008.

34 A scenario is (EEA 2009: 6): "[…] a consistent and plausible picture of a possible future reality that informs the main issues of a policy debate," sometimes also-called a snapshot scenario.

35 Accordingly one can distinguish between more static and more sequential scenarios (e. g. Schweizer 2010).

foresight, not *one* scenario, but *several alternative* scenarios are constructed to represent future openness or uncertainty.[36] Scenarios are constructed during so-called scenario *processes*. Ideally, these can be split into different phases (cf. e. g. Kosow/ Gaßner 2008: 17 ff., Kosow/ Leon 2015):[37] Phase 1, *framing and scoping*; phase 2, *identification of scenario (key) factors* (also-called scenario elements, drivers or descriptors); phase 3, *analysis and selection of alternative future developments* of these factors (also-called variants) and of their dynamics over time; and phase 4, *bundling* of variants into comprehensive scenarios and selection of a (small) set of scenarios (*sampling*). Once scenarios are constructed, diverse analysis steps, also-called *scenario transfer,* can follow in phase 5. In different schools of scenario construction, these phases are designed in very different, more or less explicit forms, and sometimes carried out in a different order (see sections 2.2.2 and 2.2.3). As the core approach of futures studies, scenarios are produced and used in its diverse *fields* (cf. e. g. Van Notten et al. 2003, Alcamo/ Henrichs 2008,. Currently, environmental scenarios on the one hand (cf. Rothman 2008) and business scenarios on the other hand are seen as main fields of application (cf. e. g. Tourki/ Keisler/ Linkov 2013).

Scenarios are constructed for various *aims and functions* (cf. e. g. Greeuw et al. 2000, van Notten et al. 2003, Alcamo/ Henrichs 2008, Kosow/ Gaßner 2008):

a) To explore possible alternative futures (cognitive or explorative function).
b) To support decision making, e. g. by testing policies, formulating normative goal scenarios and building strategies.
c) To learn, e. g. to develop a shared, inter- and transdisciplinary understanding of problems and of complex systems.
d) To communicate and to raise awareness.

Scenarios are *used* by different groups of actors; e. g. decision makers (cf. Parson 2008, who distinguishes different types of decision makers), researchers, journalists, etc. Pulver and van Deveer (2009) propose to distinguish between those actors who were included in the scenario construction itself, e. g. “producer-users” (internal users) and other (potential) “recipient-users” (external users).

Scenarios perform through what is called boundary work (cf. Jasanoff 1990), linking different social worlds such as science and humanities, the natural and social sciences, and even the different subdisciplines and styles within natural science communities (Garb/ Pulver/ VanDeveer2008: 3). Parson (2008: 5) stresses that scenarios are always under critique and *contested* because they are tools in political discourse.

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36 I chose to use the term ‘scenario construction’, and not its alternatives (development, analysis, building and so on) to stress the socially constructed and crafted character of scenarios.

37 The number and name of these phases differ across authors (see e. g. Gausemeier et al. 1996 vs. Wilson 1998 vs. Steinmüller 2002).

For their various aims, a *multitude of different scenario methods and techniques* was developed. Various classifications and typelogies of scenario approaches are proposed in the literature (see e. g. Greeuw et al. 2000, van Notten et al. 2003).[38] One can distinguish between forecasting approaches, that is developing *exploratory* scenarios (e. g. by asking "what-if" questions, vs. backcasting that is developing *normative* scenarios by asking "Where do we want to go?" and then "How do we get there?") But beyond this analytical distinction, exploratory scenarios are not free of normative elements (see e. g. Greeuw et al. 2000) and explicitly normative scenarios also include descriptive elements anchored in shared knowledge of past, present and future conditions. Furthermore, one can distinguish between *expert* approaches carried out by modelers, researchers and experts of all kinds and *participatory* approaches, including decision makers, stakeholders or even laypeople (cf. van Notten et al. 2003).

These scenario methods comprise so-called *qualitative* approaches, covering a broad range from very intuitive-creative to systematic-formalized techniques; and so-called *quantitative'*approaches, numerical techniques of all sorts including modeling and simulation; and finally so-called combined, or integrated qualitative-quantitative approaches. All three types of approaches structure scenario construction processes in specific ways and impact the resulting *scenarios*. That is to say, the three result in text (more or less narrative storylines, pictures, movies etc.), or in numerical information (numbers, graphs), or in forms of combined or integrated textual, visual and numerical scenario presentations, respectively.

A current overview of the growing scenario literature is provided by Tourki, Keisler and Linkov (2013). The authors have analyzed n= 342 peer reviewed papers on scenario analysis from 2000-2010. Their meta-analysis shows first that most papers focus on exploration but that decision making is increasingly stressed as an explicit goal. Second, that environmental applications are dominant (ca. 60%), and that one third of these environmental papers deals with climate issues, and "more than 70 percent of the environmental papers refer to the SRES by IPCC 2000." (Tourki/ Keisler/ Linkov 2013: 8). Third, the number of scenario papers per year has strongly increased, mainly due to environmental and business applications. Finally, the authors observe a trend towards more formalized (in contrast to intuitive) approaches,[39] which might be linked to the scientific, data- and model-oriented (i.e. more positivist) scenario culture predominant in environmental research—that also dominates the type of academic publications sampled by their study.

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[38] Cf. also Rotmans et al. 2000, Bradfield et al. 2005; Mieztner 2009, Schweizer 2010, Amer/ Daim/ Jetter 2013 and many others.

[39] "As for the trend, only a handful of the SA papers implementing formal approaches was published between 2000 and 2003; the number of such papers increased significantly in 2004–2007, and over 20 formal SA papers were published in the last 2 years under review." (Tourki/ Keisler/ Linkov 2013: 8).

2.2.2 Qualitative scenario approaches

So-called qualitative scenario approaches comprise a large variety of approaches that use fairly 'soft', meaning intuitive and less formalized (and clearly non-numerical) techniques. They construct possible futures and pathways leading to those futures mainly in qualitative, textual or visual form, e. g. in the form of storylines. Note that the field of qualitative approaches is itself very heterogeneous, covering a continuum of narrative, intuitive, creative, evolutionary and participatory approaches at one end of the spectrum, and analytic, systematic and (semi-) formalized but still qualitative key factor approaches at the other end (cf. also e. g. Mietzner/ Reger 2004, Kosow/ Leon 2015).

The more narrative-creative, intuitive and participatory approaches comprise *normative-narrative scenarios* (Gaßner/ Steinmüller 2006, 2009); the '*scenario axes'* (Schwartz 1991; van der Heijden 1996) working with two (independent) centrally important uncertainties, of which two extreme developments are defined and combined to span a four field matrix structuring a scenario sample (cf. e. g. Henrichs et al. 2009)[40]; and finally, and central to this study, the approach called *intuitive logics* (IL) (Huss/ Hunton 1987, Wack 1985a,b, Wilson 1998), which has its origins in the business context. Its central feature is that the scenario builder works with the experts who know best about the issue being studied, using all sorts of available knowledge, including intuitive forms (Wilson 1998). The scenario logic is built around the main uncertainties in the form of narrative texts with "compelling storylines" (Morrison/ Wilson 1997)" and "highly descriptive titles" (ibid.). IL is sometimes used in combination with the scenario axes approach. Some of the most famous examples of qualitative scenarios are the early scenarios by SHELL (cf. e. g. Wack 1985a, b; van der Heijden 1996, Bradfield et al. 2005).

The more systematic-analytic approaches comprise *morphological analysis* (e. g. Ritchey 2007), *impact analysis* (IA) (Vester 2002), and *consistency analysis* (CA) (Rhyne 1974, Reibnitz 1991), all of them belonging to the more general field of soft systems thinking and *qualitative* systems analysis (cf. Churchman 1970; Ackoff 1974; Checkland 2000). Some varieties of *cross-impact analysis* (CIA) (e. g. Gordon/ Hayward 1968), are in a family of approaches that fall into either the qualitative or the quantitative (cf. e. g. Weimer-Jehle 2014). Often, these systematic-analytic approaches are supported by scenario software and can result in rather high numbers of scenarios. These systematic approaches are associated with the French scenario school following Berger and Godet (e. g. 1999) as well as with the German-speaking scenario school of the Battelle institute (e. g. Reibnitz 1991, Geschka 1999). These have been bundled into the so-called *formative scenario analysis* (FSA) (Scholz/

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40 For an ethnographic study revealing different functions this approach fulfills in scenario processes, see van't Kloosters/ van Asselt 2006.

Tietje 2002).[41] As stated above, Tourki /Keisler/ Linkov (2013) noted a current trend towards—or rather a revival of—more formalization in the scenario world, linked to the next group of approaches, the quantitative ones.

2.2.3 Quantitative scenario approaches

So-called quantitative scenario approaches comprise those that use fairly hard, systematic and formalized techniques to construct possible futures and the pathways leading to them—mainly in numerical form (e. g. through numbers, indicators, and graphs). First, there are those approaches from the *cross-impact* family that fall rather onto the (semi-)quantitative side (cf. again Weimer-Jehle 2014); second, there are approaches using (single) *trend analysis, trend extrapolation and trend impact analysis* (e. g. Gordon 1994) to calculate future developments; and finally—and these are the ones that are of further relevance to this study—so-called *model-based scenario approaches* using hard systems thinking (e. g. Forrester 1958, 1971) and formal systems analysis as mathematical modeling and simulation to construct scenarios. To describe how these models are used to build e. g. environmental scenarios, I need to clarify first what I understand by a model?[42] Following Baumgärtner et al. (2008: 8): „A model is an abstract representation of a system under study, explicitly constructed for a certain purpose and based on the concepts within a scientific community's basis construction of the world that are considered relevant for the purpose." During model building, actors need to take several decisions (cf. e. g. Imboden/ Koch 2008: 4 ff. and very similarly also Baumgärtner et al. 2008):

- What is the system? What is taken into account and what not, what is in- what is-outside? (Establishing boundaries between the system and its environment.)
- What elements of the system (system variables) are considered?
- What are the interactions within the system (internal relations)?
- What are the interactions of the system with its environment (external relations)?

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41 For an overview of the different schools, c.f. Mietzner/Reger (2004), Bradfield et al. (2006), Amer/Daim/Jetter (2013), Seefried (2014).

42 A large variety of definitions and types exists, an early classification was tried by Kornbluh and Little (1976: 9), see below, a more current classification was proposed by Borshchev and Filippov (2004).

THE NATURE OF A COMPUTER SIMULATION MODEL

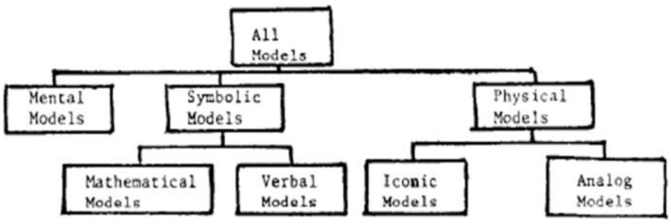

Fig. 1. Types of models.

Source: Kornbluh/ Little 1976: 9

These decisions define the *type* of model that is built and are taken in response to the *purpose* of the model (cf. Baumgärtner 2008, Giere 2004, Imboden 2008: 7 f.). As Frank (2008) puts it "you cannot construct a model for a system but only for a question." There is a large variety of models and modeling approaches. Models that are relevant for quantitative scenario construction are *formal* and *numerical* (or mathematical) and (unlike *conceptual* models) consist of formalized relations of abstract entities and *empirical* models (as opposed to *theoretical* models). Depending on the kind of interrelations that are represented, one can distinguish *static* and *dynamic* models with dynamic modeling focusing on the causal relations driving the processes of a system (cf. Imboden 2008: 16 ff.). Depending on the rules and laws assumed for interrelations, one can distinguish between *deterministic* and *stochastic* models (cf. Imboden 2008: 16 ff.).[43] In environmental scenario analysis, mathematical models (and model groups) are used to *simulate* possible future system developments of environmental systems. *Simulation*, means, very roughly, to do as if. In science and research, (computer) simulation is used to imitate or to replicate one kind of process (e. g. a natural one) in another kind (e. g. a numerical one) (cf. e. g. Spath 2009) to gain knowledge about dynamics and interrelations and or about possible future system states. Simulations, very broadly speaking, aim to explain, make prognoses and control a system. More specifically, they aim to identify system levers, analyze system stability and test policy interventions.[44] (*Computer) simulations* can be understood as '(numerical) modes that are put into motion'.[45] An *environmental simulation* often involves calculating how environmental systems develop over time, for instance by assuming a specific level of human activity driving this system development. Environmental simulation is used to explore possible *future* system

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43 Furthermore, the levels or '*scales'* (*global, regional, local, e. g.)* and the degree of *abstraction* is distinguished (Borshchev/ Filippov 2004) with regard to the direction of integration. There are „*bottom up*" vs. „*top down*" models, with the top down perspective working on the macro level of aggregate values and the bottom up perspective constructing a model from the micro level, including elements that have empirical correspondences. Borshchev and Filippov (2004) state that, outside of academe, there are four modeling paradigms with different user communities:

- *System Dynamics*, mainly used in management that represents processes through „Stocks, flows and their causal relationships"; based on interacting feedback loops.
- *Discrete Events*, mainly used by industrial engineers), creating representation through "entities and resources (passive objects), flowchart blocks (queues, relays etc.)."
- *Dynamic systems* used by control engineers e. g., representing processes through „blocks (Integrator, Gain, Delay…); Block diagram with feedback loops". These three are "Three practitioners' communities (three different worlds) that never talk to each other" (Borshchev/ Filippov 2004: 4).
- Finally, they see a fourth paradigm emerging (which has by now been established), namely *Agent based modeling,* in which "individual objects with local behavior rules drive the model. Objects interact with each other and the environment" (ibid. 7), agents act according to specific rules on the micro level, and the overall model represents system behavior.

44 For more detail on the multiple *aims* of simulation and their *justification*, cf. Grams 2008, Baumgärtner 2008, Arnold 2008.

45 VDI-guideline 3633: „Simulation is the imitation of a system with its dynamic processes in the form of a model that allows for experimentation, in order to gain insights that can be transferred to reality." (The German original reads: „Simulation ist das Nachbilden eines Systems mit seinen dynamischen Prozessen in einem experimentierfähigen Modell, um zu Erkenntnissen zu gelangen, die auf die Wirklichkeit übertragbar sind.")

behavior in the form of mathematical experiments by exposing the modeled system to a specific stimulus and observing what happens (cf. also Dieckhoff 2015). Concretely, models are built (or adapted); model runs are executed based on specific input data sets, that is assumptions on external influence that are fed into the model. These are drivers of the processes that change the system, which is represented by the model; and the model calculates indicators, i.e. model output. [46] To give a simple example from the field of climate change scenarios (that is in the general sense of the IPCC Third Assessment Report 2001), assumptions on e. g. future GDP development and population growth are used to drive so-called emission models that allow future greenhouse gas emissions to be calculated. To represent the future uncertainty of human activity, GDP and population growth rates are varied, commonly through sensitivity analysis. Then, greenhouse gas emissions calculated using the first model(s) are used as input to further environmental models, such as atmospheric, earth and ocean models, to calculate future temperature developments of the atmosphere, the so-called 'climate scenarios'. The same basic principle is also used in other environmental fields.

Model-based environmental scenarios are intended primarily for scientific research (cf. Alcamo und Henrichs 2008, Alcamo 2008), that is to explore the future state of the environment ("What if?"), but they can also be used to support decision making and planning through the identification of emerging problems and of the future consequences of current policies, and to support the search for policies to prevent negative future effects. These two motivations are also seen by Baumgärtner (2008: 8), who distinguishes between a cognitive interest to understand the world and future vs. an action interest to manage the world, based on an idea of how it might turn out to be.

2.3 Combined scenario approaches

A brief sketch of the field of combined scenario approaches sharpens the perspective and wording used in this study (2.3.1). Then, I present the state of the art on combined scenarios: I introduce the concept of the dominant SAS approach (2.3.2) and review empirical experiences with combined scenario approaches (2.3.3).

2.3.1 Focusing the field

In environmental scenario analysis, combined scenario approaches have been developed in the last 15 years that propose to combine storylines—meaning qualitative, textual or even literary descriptions of societal (political, institutional, etc.) futures—with numerical modeling and simulation. In the

[46] For an overview of how a software based (modeling and) simulation process are carried out, see e. g. Grams (2008: 11), who makes a rough distinction between four phases: phase 1) problem definition, phase 2) model building (including validation and verification), phase 3) simulation experiments and phase 4) presentation of results. For more details, cf. also Banks (1995), and Frank (2008).

following, the field of combined and integrated scenario approaches, as understood in this study, is more specifically defined.

When looking at its boundaries, the field appears large and fuzzy, covering various combined forms of qualitative and quantitative scenario elements in various fields of application. This fuzziness has two central reasons. First, the field touches on larger and older debates that go far beyond the construction of futures scenarios. For instance, the issue of combining quantitative or hard systems thinking (cf. e. g. Forrester 1958, 1971) with qualitative or soft systems thinking (Churchman 1970; Ackoff 1974; Checkland 2000) was debated in systems thinking. Also, how to bridge the “qualitative-quantitative divide” (Tarrow 1995), was discussed for decades in the social sciences. [47] The central lines of these debates are first, whether one of these approaches—the qualitative or the qualitative—is of higher value; and second, what role both perspectives should play for each other and for the overall research process (cf. e. g. Andersson 1974, Kelle 2007, Tarrow 1995). Across these different fields, ideal typical positions can be summarized as comprising those favoring integration by striving for quantification and mathematization; and those emphasizing the unique strengths of both approaches, favoring combinations in which both components maintain their specific characters.

Often the first position underlies neighboring approaches, as in System Dynamics modeling (SD), Agent Based modeling (AB), and Integrated Assessment modeling (IA). As combined scenario approaches, these approaches are all concerned with the challenges of combining and integrating qualitative and quantitative knowledge and of translating qualitative information into model-relevant information (cf. e. g. Yang/ Gilbert 2008, Seidl 2015). Still, these approaches are not the focus in this study, as long as they are not explicitly used to construct *future* scenarios—and in addition, combined with *qualitative* techniques of *scenario construction*.

Second, the boundaries of the field of combined scenario approaches are rather blurry, because many scenario processes and presentations (model-based ones as well as those based on creativity workshops, for example) do, at some point, combine textual and numerical elements. Still, combined scenario approaches like the ones analyzed in this study are only those which do combine qualitative and quantitative approaches to scenario *construction* — and not only to scenario *presentation*. Looking at the center of the field, the literature on combined scenario approaches *in environmental research* clearly appears to be dominated by Alcamo’s SAS approach. This is a specific approach combining intuitive logics to derive input data sets for simulation runs to construct *exploratory* scenarios (cf. 2.3.2). But, next to the label SAS, combined scenario approaches are also-called “integrated scenarios” (e. g. Döll/ Krol 2002), “narratives and numbers” (e. g. Kemp-Benedict 2004), or “hybrid

47 Please consider the method dispute in the empirical social sciences between the more positivist, quantitative and the more constructivist, qualitative research.

scenarios" (e. g. Winterscheid 2008). When it comes to the practice of combined environmental scenarios, whether realized within or outside the framework of SAS, there is a rather large spectrum of empirical designs (cf. also 2.3.3).[48] In this study, I use the term combined scenario approach when I refer to the entire field. This is in my view the most neutral and least ambitious term, as not every combined approach is or strives to be a (deeply) integrated one. I use the term 'SAS-type approach' for the mainstream type of combined scenario approaches used in the field of environmental scenarios.

In the following sections, I present the SAS-type approach, because it is the best documented approach, and, to my knowledge, the only one providing conceptual considerations going beyond individual applications (2.3.2).[49] The later review of empirical experiences also provides a glimpse of combined scenario approaches more generally (2.3.3).

2.3.2 The SAS-type approach

In the following, I start by briefly summarizing the basic idea of combined scenario approaches of the SAS type; I then sum up the expected functions of this approach; finally, I sum up what the literature says about how to carry out SAS processes.

2.3.2.1 What are combined scenario (SAS-type) approaches?

The basic idea of combined scenario approaches is to explore futures of coupled human-(technological)-natural systems by combining numerical simulation models with qualitative storylines (or narratives). Under the label of SAS, the approach was successfully promoted by Alcamo (e. g. 2001, 2008) in the fields of environmental change and integrated environmental assessments. In parallel, methodological reflections on this type of combined scenario—without using the label SAS—have also been formulated, e. g., by Raskin and colleagues (2002), Swart, Raskin and Robinson (2004); Kemp-Benedict (2004) and Winterscheid (2007).

The basic idea of combined scenario approaches type SAS (cf. Alcamo 2001, 2008, Raskin et al. 2005) is to first construct a broad set of qualitative storylines,[50] to translate the driving forces of the storylines into quantitative sets of input data for the numerical model, and to use these sets for scenario simulation, see Figure 3. The SAS methodology results in hybrid scenarios, comprising qualitative context descriptions and quantitative model calculations of system consequences. The input data

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48 Combined scenario approaches have been developed in fields other than the environmental, e. g. in economics. For instance, a very early approach can be found with Fontela and Gabus (1974, see also Fontela 1976, 1977), who propose to use a formative and semi-qualitative scenario approach that provides input parameters for an economic input-output model.

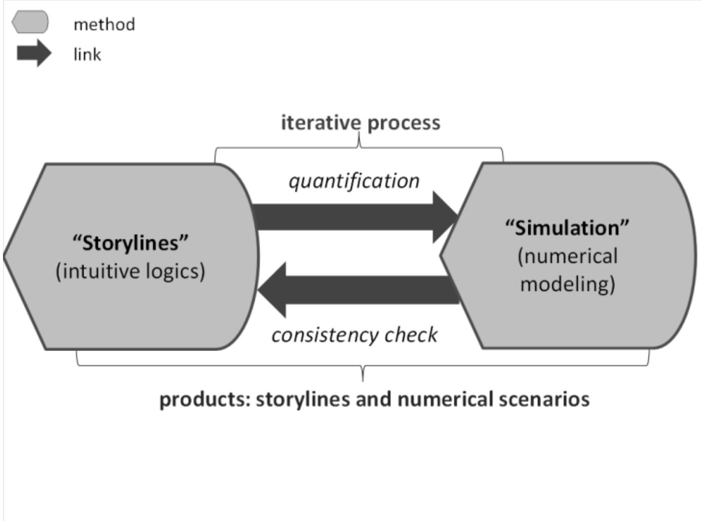
49 The risks related to this focus on SAS-type approaches are discussed in chapter 8.

50 Storylines are often constructed together with experts in the form of workshops.

sets, also-called driving forces, build the "first half" of the numerical scenarios; and the outputs, also-called indicators, build the "second half" of the numerical scenarios (Döll/ Krol 2002: 310).

Figure 3: Vizual summary of the SAS approach

My illustration, based on Alcamo 2008.



The approach relies on the principles of *consistency control* and *iteration*: The authors suggest that modeling and simulation are used to identify inconsistencies in the storylines (Alcamo [2008] and others), and thus recommend revising the storylines after simulation. Iteration may then become necessary, adapting the input data sets to the refined storylines and repeating the simulation.

2.3.2.2 Why use combined scenario (SAS-type) approaches?

There are several assumptions underlying the use of combined scenario approaches of the SAS-type, that hint at far older ideas of systems and future thinking and of inter- and transdisciplinary integration. In the literature, across authors, I have identified three main arguments that are used to justify, *why* to use these combined scenario approaches:

The combination benefits from the advantages of both, qualitative and quantitative approaches

The first assumption is that so-called qualitative- and quantitative-scenario approaches have specific advantages and disadvantages (cf. also section 2.2 above), and that their combination could benefit from the advantages of both and counterbalance their respective weaknesses (e. g. Raskin et al. 2005: 36; Alcamo 2008: 124; Kemp-Benedict 2004:1; Winterscheid 2007: 54, Swart/Raskin/ Robinson 2004: 140). A summary of the respective advantages of the two types of scenario approaches, as seen by Alcamo and Raskin, is given in Table 1.

Kemp-Benedict (2004) argues that complexity, especially of social systems, is best dealt with by narratives, „complicatedness", meaning „keeping track of the numerous influencing factors" (Kemp-Benedict 2004: 2) is better represented by computer models that are able to calculate standardized operations in a timesaving manner. Raskin and colleagues (2005: 37) summarize: "A central challenge

[…] is to unify these two aspects by blending the replicability and clarity of quantification with the richness of narrative.” In sum, the combination is assumed to allow for a more appropriate representation of complexity and uncertainty and thus for a deeper and more comprehensive understanding of the system under study (cf. e. g. Alcamo 2008, Winterscheid 2008, Kemp-Benedict 2004). The assumption is that this is realized by combining qualitative and quantitative data and information, combining knowledge of detail and knowledge of synthesis, and by allowing reflection and cross-checking of more than one (namely the model-based) perspective, which is explained in the following.

Table 1: Advantages of qualitative vs. quantitative scenario approaches, as seen by Alcamo (2008: 124 ff.) and Raskin and colleagues (2005: 36 ff.).

Qualitative scenario approaches Ideal type: storyline or narrative text	**Quantitative scenario approaches** Ideal type: based on computer models
Represent heterogeneous perspectives of diverse stakeholders and experts. More interesting and comprehensive than „dry tables of numbers or confusing graphs“(Alcamo 2008). Useful to collect experts' and policy makers’ views on future social developments and their environmental implications. Support for considering the bigger picture, including long time horizons and great geographical scales. Useful when communicating issues and raising awareness. Useful for the development of strategies.	Provide numerical information and satisfy demand for quantitative scenarios from environmental science and policy. Assumptions are—at least in principle and for experts—transparent (equations, inputs, etc., documented). Based on published models (quality control via peer review). Useful for exploring what assumptions have what environmental effect. Useful for policy test and policy advice.

Combined approaches allow getting out of the dominance and specific perspective of numerical models

The second assumption is that through the use of qualitative scenario approaches in combination with numerical modeling, we get out of the diagnosed dominance (Kemp-Benedict 2004: 1)[51] and specific perspective (Rounsevell/Metzger 2010: 608)[52] of using numerical models alone and instead, obtain a more balanced perspective (Kemp-Benedict 2004: 1).[53]

Combined approaches allow us to make implicit models explicit

The third assumption underlying SAS is that through the combination of approaches, underlying models can be made explicit. This assumption is based on the perspective that both qualitative and

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[51] "Modelers, in particular, have cast themselves as the guardians of rigor in a field struggling to gain legitimacy, and it can perhaps be stressed that in the past decade with the increasing use of Integrated Assessment (IA) models and Computable General Equilibrium (CGE) models, *quantitative models have dominated*." (my emphasis). See in the same line of argumentation for sustainability research Swart, Raskin and Robinson (2004: 138).

[52] “The Global scenario-group (GSG), convened in 1995, realized that complementing quantitative modeling techniques with qualitative scenario exploration would provide a broader perspective than is possible from mathematical modeling alone.”

[53] "(…) the weaknesses of quantitative models have once again become apparent […], there are increasing calls for balancing qualitative and quantitative approaches in future work."

quantitative scenario approaches operate with a sort of "system model" (Walker et al. 2003: 7), namely with *hard models* (numerical computer models, formalized models) and or *soft models* (verbal or conceptual models). Kemp-Benedict (2004: 2, my emphasis) differentiates: "In the mathematical approach, the model is *explicit*, as a set of mathematical formulae, a computer program, a diagram in Stella or some other formal representation that can be translated into a sequence of numerical calculations." Still, the explicit, hard and quantitative component itself is based on further *implicit* assumptions (e. g. on contexts that impact decisions on inputs and/or parametrization), or as Winterscheid (2008: 37) turned it: "Hard system models *always* interact with soft system models"[54] as every formalized element and relation is linked to a *qualitative* understanding.

On the other hand, "in the narrative approach, the model is generally *implicit* in the form of the narrative which reflects the shared *mental model* of its authors" (Kemp-Benedict 2004: 2, my emphasis). Qualitative scenarios and narratives mirror these mental models and make them, at least in part, verbally explicit and accessible for reflection, discussion and critique. Thus, both types of model are based on implicit assumptions that, such is the expectation, *could* become *more* visible through the combination of storylines and simulation models.

Considering these three assumptions, some questions arise: Are they actually fulfilled by SAS-type approaches? Or is it rather the case that the combination suffers from the limits of both approaches? And does the combination not allow the continued dominance of model-based thinking, including a rather positivist perspective when, so to say, calculating the future? And, finally, do assumptions and mental models behind storylines and behind numerical models not rather remain implicit?

2.3.2.3 How does one carry out combined (SAS-type) scenario processes?

Overall, the methodological combination is not a consolidated out-of-the-box method (cf. Döll 2003/2004: 398). There *is no consensus* about how to do the combination (cf. Kemp-Benedict 2004: 1), and SAS is a rather general methodological framework that is conceptually rather weak. The construction of hybrid scenarios was conceptualized by different authors as a *process* in several steps. For instance, Alcamo (2001 and 2008) proposes an idealized SAS process in ten steps based on several empirical applications on the global level.[55] Döll (2003/2004) presents her version of the process to construct "qualitative-quantitative scenarios" in seven steps based on two applications in the field of water management. Winterscheid (2007) drafts a detailed concept for a process to construct "hybrid scenarios" for flood risk management in four phases. For an overview of the different process models, see Annex B.[56]

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54 The original German reads: "Harte Modelle interagieren stets mit weichen Modellen."
55 This study refers to this SAS definition as the 'ideal type' or 'classical SAS'.
56 The authors also refer to each other and integrate the work of the others.

First of all, the three approaches share the *basic idea*s of : a) building qualitative scenarios on possible future developments (storylines); b) *quantifying* these; and c) using the quantified assumptions as input data sets for model runs (simulation) to calculate indicators (that is output parameters of the models). With regard to the quantification or translation of storylines into numerical input data sets, different intuitive or formalized conversion techniques have been proposed.[57] Second, all authors share the idea that the process needs *iteration*, meaning that the process is not linear; rather, loops are necessary in which both components are compared, used to inform each other, and to *refine* the qualitative and the quantitative formulations of the scenarios.

The description by Alcamo is most explicit and detailed with regard to the definition of the *social organization* of the process and the distribution of tasks. He proposes (2008: 137 ff.) to compose a *scenario team,* that is a small core group responsible for the coordination between the *scenario panel* and the *modeling team.* The scenario panel, often also-called scenario group, is a bigger group, responsible for the qualitative storylines and which can include additional stakeholders and experts; the modeling team is responsible for the quantification of the assumptions and the modeling. Alcamo stresses that in the scenario team, experts are required, who know what quantifications are necessary and what quantifications are possible (cf. Alcamo 2008: 138). He gives an explicit role to *decision makers* in the phase of the process when the scenarios are distributed for general review. Döll's description is more specific with regard to the technical level. She points to the need to define indicators of system states, depending on the mathematical models *available for quantification very early* in the process, namely *before* the definition of qualitative scenarios. Winterscheid (2008) adds two aspects, namely the simulation of interventions and the evaluation of scenarios with regard to predefined (sustainability) criteria, both aspects further define the phase of usage or assessment of the scenarios.

2.3.3 Empirical experiences with combined scenario approaches

In the following, I sum up my literature review about empirical applications of combined scenario approaches in the field of socio-environmental scenarios.

2.3.3.1 Aims and sampling of the literature review

The aims of this review were to learn from the experiences of others; to learn what different *types of combination* already have been empirically tried out; and more specifically, to look for *dimensions* that might be important in the design of such approaches. Thus I did not aim for a comprehensive catalogue of all existing applications, but focused on learning about the range and characteristics of

[57] Alcamo (2008) as well as Kok and colleagues (2015) proposes using fuzzy logic; Kemp-Benedict (2010) proposes using Bayesian statistical reasoning, both approaches are rather systematic Winterscheid (2008) proposes verbal argumentative logic, a rather intuitive approach. Still, all of them, in the end, rely on expert judgments. For a more detailed comparison, see Annex C.

currently used methodologies. Therefore, I started to review the four prototype applications of SAS on which Alcamo explicitly bases his approach (in chronological order). These are the World Water Vision (Gallopin/ Rijsberman 2000, in the following abbreviated as 'WWV'); the perhaps best-known application in the field of *climate change research* are the emission scenarios documented in the IPCC SRES report (Nakicenovic et al. 2000 'SRES'); the Millennium Ecosystem Assessment on *biodiversity* (Carpenter et al. 2005 'MEA'); and the Global Environmental Outlook, with the GEO-4 scenarios on *sustainability* (UNEP 2007, Rothman/ Agard/ Alcamo 2007 'GEO-4'). These four are applications on a global scale and in the form of fairly large exercises in terms of actors, resources, and time. Each of these four projects reveals an individual methodological design that deviates from the ideal typical SAS approach (cf. also Alcamo 2008).

To broaden the view beyond these SAS-prototypes, I have included further examples of combined scenario exercises. The examples chosen go beyond those explicitly referring to the apparently dominant SAS-type approaches and also comprise studies from neighboring fields. Mainly based on a snowball-system of asking experts in the field and on cross-references, I found diverse other combined scenario exercises on different scales (geographically and in terms of resources) and in different socio-environmental fields.[58] These were mainly in the fields of *water management* (e. g. Döll/ Krol 2002 and Döll 2003/2004 'WAVES'; van Asselt et al. 2001a and 2001b 'IRMA', Government office for Science 20014,[59] Wheater/ Evans 2009 'FFCD'; Kamäri/ Alcamo et al. 2008, Vliet/ Kok 2008, Vliet et al. 2012 'SCENES') and *land use* (e. g. PIK 2004 and Rounsevell et al. 2005 'ATEAM', EEA 2007b and Volkery et al. 2008 'PRELUDE', Westhoek/ van den Berg/ Bakkes 2006 'EURURALIS'; Kok/ Van Delden 2009 'MedAction'), but also *sustainability* (Gallopin et al. 1997 and Raskin et al. 2002 'GSG', Rotmans et al. 2000 'VISIONS'). In addition, I Included combined scenario approaches that have been developed and applied in neighboring fields such as *industrial ecology* (cf. e. g. Hilty et al. 2006 'ICT'), *economics* (cf. e. g. Böhringer/ Löschel 2005 'EMF') and more recently also in *energy research* (Trutnevyte/ Stauffacher/ Scholz 2011 'URNÄSCH', Trutnevyte et al. 2012 'APPENZELL'). Annex D gives more detailed information on this sample of studies.

2.3.3.2 Characteristics of different empirical designs

The studies show a large variety of approaches combining numerical models with qualitative storylines (see Annex E for their individual characterization).

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[58] In the end, I included only those examples for which I could obtain a minimum of information (and where possible also some reflection) on the *methodology* that was used. In total, I reviewed a selection of n= 18 scenario studies using a combined scenario approach. Some of them group themselves under the SAS umbrella, others do not.

[59] URL: https://www.gov.uk/government/publications/future-flooding

The designs share several characteristics. First, they require time: Projects take no less than two years and can take up to five years or longer. Often, they require more resources than initially planned. Many researchers report that there was too little time and resources, leading to adaptations of the initially planned design (e. g. GEO-4). Almost all of the studies have the explicit double aim of scientific exploration and policy advice. Some also explicitly intend to foster communication and awareness (e. g. GSG, VISONS, MedAction) and a few also explicitly focus on method development (e. g. SCENES).

Furthermore, the *qualitative scenario techniques* used in almost all of these exercises belong to the creative-intuitive end of the spectrum. Many can be identified as forms of the intuitive logics (IL) approach (cf. Schweizer 2010: 7 ff.), even if not always labeled as such. Often, 'scenario-axes' are used to select and construct scenario samples (e. g. SRES, FFCD, EURURALIS). Another approach is to use normative archetypes (e. g. GSG, IRMA) and visions (e. g. URNÄSCH, APPENZELL). The only study using a systematic formalized approach, namely a probabilistic form of cross-impact analysis (CIA), is EMF. Also, most qualitative storylines, scenarios and visions have been developed in *participatory* approaches including experts and stakeholders. Only a few were based on desk research by experts (e. g. ICT, EURURALIS). Furthermore, qualitative scenarios are often heavily based on an existing storyline developed by others (e. g. on those of the GSG, the SRES, GEO-4 etc.).

In contrast, approaches diverge with regard to *the type and number of numerical model(s)* that are used. They range from large integrated ecosystem modelling *groups* (e. g. MEA) through individual small system dynamics models (ICT) to decision support systems (MedAction). In most studies, models *pre-exist* the scenario exercises (e. g. SRES, MEA, GEO-4) and are only rarely completely newly built (e. g. ICT, WAVES in part).

Furthermore, approaches implement different forms of *division of labor* across storylines and mathematical models; these are stylized in Table 2.[60]

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[60] In Alcamo's SAS approach, storylines cover *qualitative* aspects, models cover the *quantitative* or quantifiable aspects of the system under study. This division of tasks can go hand in hand with a division between *social sciences* aspects vs. *natural sciences* aspects, suggested by the division in socio-economic storylines and natural sciences models, as in the case of the SRES (2000). However, theoretically, a combination of quantitative projections made with an econometric model with a qualitative model of environmental systems, such as by a Syndrome Approach model (WBGU 1998), is imaginable, too. Also, this division does not have to follow disciplinary lines, since some social-sciences aspects are easily quantifiable and thus representable by numerical models. Some natural sciences aspects, for example, the ecological features of a system can only be described qualitatively (see MEA, where the storylines have covered explicitly the non-quantifiable aspects of the natural systems representation, too). Along these lines, but more extreme, is the division between science vs. the uncertain and messy: Numerical models deal with the *scientific facts* (and are calibrated and validated by historical data), qualitative scenarios take over the burden of filling knowledge gaps and representing *uncertain futures,* which always depend—at least to a certain degree—on qualitative expert assessments, fears, hopes (cf. Grunwald 2011) and normative positions. Al-

Table 2: Division of labor – foci of the two components (stylized summary)

<table>
<tr><th colspan="2">Qualitative storylines</th><th colspan="2">Numerical models</th><th>Example(s)</th></tr>
<tr><td rowspan="3">Qualitative aspects</td><td>Socio-economic-institutional (etc.) contexts (drivers)</td><td rowspan="3">Quantitative aspects</td><td>System changes</td><td>Ideal typical SAS, MEA</td></tr>
<tr><td>Policy regimes</td><td>Evaluation of effects</td><td>EMF</td></tr>
<tr><td>Normative visions</td><td>Multiplicity of technology portfolios</td><td>APPENZELL, URNÄSCH</td></tr>
<tr><td colspan="2">Social sciences aspects</td><td colspan="2">Natural sciences aspects</td><td>SRES</td></tr>
<tr><td colspan="2">Assumptions, fears, hopes (the future)</td><td colspan="2">Objective analysis, facts, truth (the past)</td><td>MedAction, WAVES</td></tr>
<tr><td colspan="2">Social scientists, stakeholders, laypeople</td><td colspan="2">Natural scientists</td><td>MEA</td></tr>
<tr><td colspan="2">Intuitive and holistic thinking</td><td colspan="2">Analytic and rational thinking</td><td>URNÄSCH</td></tr>
</table>

Furthermore, the *overlap* between what is represented by the qualitative and the quantitative components diverges across studies. It ranges from little overlap, with storylines limited to model contexts (e. g. SRES), to higher degrees of overlap, with storylines also roughly covering the internal logic of the system represented by the model(s) (e. g. GSG, MEA).

Studies can be distinguished with regard to the *timely succession* of both components: consecutive, in which qualitative scenarios are developed first and then numerically evaluated by the model(s) (e. g. PRELUDE, WAVES and many others); in parallel, in which two distinct perspectives on the system under study are developed simultaneously, a narrative and a numerical one (e. g. GEO-4, APPENZELL); and iterative, in which scenarios and models are linked through input-output coupling and feedback loops (e. g. MEA, ICT).

Furthermore, combined scenario processes differ with regard to the *dominance* of the process: in several cases, the (mostly pre-existing) models dominate and frame the process (e. g. SRES, ATEAM) in others, the storylines are dominant and frame the process (e. g. WWV, GEO-4), or equal weight is given to both (MEA, PRELUDE, MedAction).[61] Kemp Benedict (2004: 3) argues that it is beneficial, when the narratives drive the process and the quantitative models are developed in response to the narratives: “Note that this salutary outcome [the clarification and sharpening of the qualitative analysis provoking discussions between modelers and scenario group] is not reached, when the quantitative model drives the analysis and the narrative follows from it." Only then are models seen to have beneficial effects.[62] Instead, Trutnevyte et al. (2011, 2012) argue that independent and equal devel-

so, the qualitative side is associated with *laypeople,* such as stakeholders and communities, whereas the models are associated with the *natural scientists* (see MEA as an example).

61 Alcamo reports that in the MEA process, an equal amount of time and effort was invested in both parts of the process (cf. Alcamo 2008: 130 ff.).

62 This form of combination, in which the *storylines lead,* is conceptually described by Kemp Benedict as a steersman or leadership approach, with „the modeling team following the narrative team‘s lead” (2004:2).He explains that in this form of combination, the models fulfill the task of bookkeeping and **„**assist the scenario developers in making a consistent and coherent narrative.“ The model’s role then is to provide solid scientific ground, i.e. "to identify the model implicit in the narrative, and interpret it in a

opment of both components is most beneficial, so that one does not limit the other a priori; instead multiple quantitative interpretations of one qualitative vision are allowed for, e.g.

This issue certainly also has a *social component* linked to the weight and dominance of actors in the process. The texts, e. g. by Alcamo (2008), and especially the paper by Volkery and colleagues (2008) “Your vision or my model?”, suggest that the modelers often have more impact, credibility and standing in the process than the scenario group. Döll (2003/2004: 397) points out that the fraction of the quantitative and the qualitative parts can strongly vary, depending on three factors: the problem at stake, the scale and the resources available**.**

Furthermore, designs differ with regard to the structure and degree of *coupling*. Some combinations are coupled through input-output coupling (e. g. MEA, ATEAM, SCENES). Others show, either in addition or instead, a soft form of coupling of both components through verbal (or normative) embedding of numerical scenario results (URNÄSCH, APPENZELL) or through numerical underpinning of narrative results (e. g. GEO-4, WWV). Some approaches have realized iterative refinements of both components (e. g. MEA, ICT, WAVES). In others, iteration is either not documented (e. g. ATEAM, EMF, SRES), or was planned but not realized, due to resource restrictions (e. g. GEO 4). Iteration is considered crucial by Alcamo for the ideal type of SAS, but not by Trutnevyte et al. (2011, 2012), working with pre-existing normative visions.

The scenario *products* resulting from these different processes are very different, too. They range from model results (data) with explicit verbal assumptions (e. g. SRES), through scenario texts with selected quantitative indicators (e. g. WWV), to scenario presentations where narratives and model results merge into one representation (e. g. MEA). Sometimes publications are split into the documentations of the combined process and of the modeling.

The approaches vary with regard to the *inclusion of actors* in the scenario building (from modelers, and technical experts to scenario groups of local stakeholders), and the organization of responsibility. Volkery and colleagues (PRELUDE, 2008) focus especially on the social interaction in their participatory scenario processes, in which—in contrast to classical SAS, as the authors emphasize—the full responsibility to develop the narratives was given to a group of stakeholders (and not to the researchers or modelers). With regard to focusing the design of the social interactions, they stress: "Scenarios can be developed without restrictions of existing models and data limitations in mind, include issues that science may not be able to model in quantitative terms, while simultaneously

formal mathematical model" (Kemp-Benedict 2004: 4), to „explore a numerical neighborhood of possibilities that is consistent with its narrative“ (Kemp-Benedict 2004: 4), to reflect temporal and spatial constraints, to offer several levers. This idea was taken up by Winterscheid (2008), who considers the storylines to be central, because they represent the underlying mental models more explicitly and more comprehensively and thus should frame and drive the development of the numeric models.

benefiting from the rigor and consistency check that models can provide." (Volkery et al. 2008: 465, my emphasis). They warn: "The participatory development of long-term environmental scenarios is a challenging process. Therefore, it is important to think carefully why and to which extent stakeholders should be involved and to clarify the roles and responsibilities of modelers and stakeholders before starting the overall process." (Volkery et al. 2008: 460).

In sum, this review of empirical experiences with combined scenario approaches shows a great variety of designs. Especially, opening up the review beyond approaches gathering explicitly under the SAS-umbrella, has shown that further forms of combined approaches are possible. Furthermore, the review hinted at the dimensions that characterize the different designs. At the same time, it showed that there is not much conceptual work reflecting these. There is a need to better understand different forms of designs and their effects.

2.4 Traceability and consistency as central challenges to combined scenario approaches

In the following, I sum up the overall critique of the SAS approach that can be found in the literature (2.4.1). Then, in more detail, I discuss its traceability challenges (2.4.2) and its promise of consistency (2.4.3), as they are the focus of this study.[63]

2.4.1 Overall critique of the SAS-type approach

In the scenario literature, SAS-type scenario approaches are critically discussed in different communities. First, there have been reflection and evaluation activities in the field of scenarios of global environmental change, understood as combinations of narratives and quantitative modeling. An initiative brought together scenario practitioners and users during a high level workshop 2007 and resulted in a special issue in the journal Environmental Change Letters 2008 (with contributions, among others, by Parson, O'Neill, Pulver, VanDeveer and Garb). Second, these approaches have been intensely discussed in the climate change community, with a special focus on the IPCC SRES scenarios and on the development of new approaches to be used from the 5th IPCC assessment report (AR5) on (cf. e. g. Girod et al. 2009, Moss 2010, Schweizer/ Kriegler 2012, Rounsevell/ Metzger 2010). Third, self-critique can be found in texts by the SAS authors themselves (cf. e. g. Alcamo 2008) also reflecting individual empirical applications (e. g. Döll/ Krol 2002 and Döll 2003/2004, Volkery et al. 2008).

Since the year 2000, SAS-type approaches have come to be seen as state of the art in scenarios of environmental change (cf. Rounsevell/ Metzger 2010: 2010). It is now a general methodological

[63] Note that the following subsections draws from earlier publications by me as e. g. Kosow 2011, Kosow 2015 and in Weimer-Jehle et al. 2016.

framework to combine numerical models and qualitative scenario techniques to develop scenarios of global change that was adapted to a variety of issues and project realities (cf. 2.3.3 above). Still, though it has plenty of appeal, the SAS-type approach is also fraught with difficulties. Its central benefits, especially when compared with modeling only approaches to environmental scenarios, are (cf. also Alcamo 2008, Weimer-Jehle/ Kosow 2011, Kosow 2011, Weimer-Jehle/ Prehofer/ Vögele 2013) are as follows: 1) Qualitative factors are not ignored and excluded, but are taken into account and included through the storylines;[64] 2) assumptions on future (social) developments behind indicators and time series used as model input do not remain hidden but are made explicit; 3) instead of assuming only one possible social future (e. g. with regard to population growth), the uncertainty of social developments is addressed through a range of storylines covering different future alternatives—and this not only for *single* developments but for several developments in form of comprehensive pictures.[65]

The key difficulties of SAS-type approaches, some of them recognized by their authors (e. g. Alcamo 2008), are the following: First, there are practical problems, as the approach is rather *resource intensive*: SAS processes are costly endeavors, mainly in terms of personnel and time because of the many workshops and meetings necessary, the time needed for iteration, and the necessary degree of engagement and commitment by participants. Volkery and colleagues give the following estimation, which matches the indications given by Alcamo (2008):

> Depending on the complexity of the issue it can take up to two or three iterative rounds to come to a common understanding about driving forces, uncertainties and final scenario logic, establishing a good working relationship between facilitator, stakeholders and modelers and finally arriving at consensus about the qualitative scenario content and its effective translation into quantitative model inputs. (Volkery 2008: 465)

Furthermore, the approach depends on *model and data availability*: To use SAS-type approaches, the models that are needed also have to be available, along with personnel with the knowledge to run them (cf. Alcamo 2008 and others). Döll and Krol remark (2002: 319): “The scenario development

64 SAS-type approaches allow to open future spaces not only in quantitative ways by using (model-based) trend projections of available indicators, but that in addition, they are able to process qualitative information. Especially when mid- and long-term futures are concerned, qualitative descriptions often are more appropriate. SAS furthermore allows combining qualitative with quantitative knowledge and thus to integrate both in a field normally dominated by quantitative approaches. SAS allows including a) different types of knowledge; b) heterogeneous participants, e. g. experts from different disciplines and also—at least in principle—non-scientific stakeholders as, e. g., decision makers.

65 The first strength of SAS consists in representing the uncertainty of future social developments by using the scenario concept in its primary sense: Possible future developments of the system under study are not driven by isolated external parameters, but are contextualized by plausible, coherent and alternative pictures of futures. System change is not driven by single predictions or projections (and varied via sensitivity analysis), but by meaningful bundles of future developments of the system and its context. Considering the fact that predictive model results strongly depend on their assumptions on uncertain external drivers; an appropriate representation of these drivers and of their uncertainty can enhance the quality of the model results in a significant way.

process is retarded, when pertinent mathematical models do not already exist for the system components or the geographical area of interest." They add that the calculation of appropriate system indicators is critical for the use of the results by external users, but that it is limited by the availability of suitable models, which in turn are limited by available data. Furthermore, these models need to be linkable to the qualitative storylines, which is not always easily and possible 1:1—as for example in the case of econometric models that are themselves based on the analysis of past trends (Alcamo 2008: 141). Literature remains silent with regard to what types of model are suitable for this kind of approach and what types are not (one exception is Kemp-Benedict 2004.)[66]

Second**,** the *conversion,* that is the translation of qualitative into quantitative knowledge, remains "one of the weakest links in the SAS procedure" (Alcamo 2008: 139, cf. also Volkery et al. 2008). Finally, it is always reliant on expert judgment, even in the application of formalized translation or conversion techniques.[67] Classically, this discursive conversion is done by expert assessments that include include expert guessing and some rule of thumb-estimates (cf. Henrichs et al. 2009, Winterscheid 2007, Alcamo 2008). Overall, translation rarely allows a perfect fit between the ideas expressed by the storylines and the data required and provided by the models. For instance, Parson stresses that mismatches between the storylines and the input needed by the modelers can occur (2008: 3).

Third, the combination of storylines with numerical modeling and simulation needs to deal with a sort of *clash of cultures*. This clash of cultures is rooted in the deep methodological and epistemological hybridity of combined approaches. Van Notten stresses that "the fusion of quantitative and qualitative data in scenarios remains a methodological challenge" (2003: 431). Volkery and colleagues report (2008: 459, 460): "However, this task is all but easy as it requires a careful balancing of approaches and an acceptance of different levels of knowledge and trust in different methods across disciplinary borders", and requires "the conscious acceptance of trade-offs between modeling capabilities and human reasoning." This clash of cultures also plays out on a social level that requires mutual understanding, respect and trust between the very diverse participants in such processes.[68]

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66 Kemp-Benedict (2004: 4) lists that a model appropriate for exploratory scenario analysis requires to:
"1. Represent the narrative; 2. Reflect fundamental constraints (e. g. land and energy balances, economic balances); 3. Reflect the spatial and temporal scales of the key processes; 4. Offer several "levers" (although not too many) for the narrative team and other users; 5. Implement likely correlations; 6. Reflect knowledge of the relevant literature."

67 See section 2.2 and Annex C for a comparison of different translation approaches.

68 One of my interview partners told me, that "the process is one of raising and deflating mutual expectations," with the typical dialogue at the beginning between scenario (S) and modelling team (M) running something like the following.
S: "Population growth?"
M: "No problem."
S: "Economics?"
M: "No problem."
S: "Governance?"
M: "Go away!"

Underlying the methodological hybridity, there is also hybridity of the epistemological perspectives within SAS-type approaches. Numerical modeling and simulation on the one hand and storylines on the other hand stem from different scenario schools and from positivist vs. constructivist paradigms (cf. also Van Asselt et al. 2010). In the words of Grunwald (2013a), they introduce the heritage of the mode 1 type of orientation provided by futures studies, namely: *predict and control the future*. On the other side, storylines, which are rooted in the constructivist paradigm of futures diversity, are seen as a means to integrate qualitative ideas on future developments, along with a large variety of actors beyond modelers, into a scenario process. Grunwald (2013a) claims that they reveal the mode 2 type of orientation provided by futures studies, namely: *design and create the future*. In sum, combined scenario approaches need to find solutions to methodological *and* epistemological tensions.

Fourth, authors report a *dominance of models and modelers,* leading to the fact that the qualitative part gets lost over time, specifically in the field of scenarios of global change: “Qualitative and narrative elements, if present at all, are less developed, less prominently reported and only weakly linked to quantitative elements. Even when scenario exercises have begun with narrative scenarios, these have faded in significance as the exercise proceeded" (Parson 2008: 3, my emphasis). Parson bases his explication of this phenomenon on the characteristics of the exercises that produce and use scenarios, namely approaches dominated by quantitatively oriented analysts and modelers that are using approaches that are familiar to them,

> First, assessments undergo intensive review processes closely modeled on scientific peer review. Scenarios that appear more scientific in character and are more familiar to participants and reviewers pose fewer risks in such a review process. On the other hand, assessments are not usually linked to any specific decision or decision maker, despite their mandate to inform decision making in general. While experience in other domains suggest users want scenarios to include uncertainties that can only be represented in qualitative or narrative terms, the weak relationship to particular users, means that such a preference finds little voice in global-change scenario exercises. *Rather, the capabilities, needs, and familiar methods of scenario producers, usually quantitatively oriented analysts and modelers are likely to dominat*e. (Parson 2008: 3, my emphasis)

One could also argue that the effective dominance of the numerical side is one solution to the inherent tension resulting from the hybridity of these combined approaches.

Finally, but along the same lines, there is a critique of the intuitive approaches, which are predominantly used to construct storylines, leading to what is perceived as an *imbalance* between highly sophisticated mathematical modeling and less systematic approaches to qualitative scenarios. For example Garb et al. (2008: 1) write: “Indeed, there is a growing imbalance between the increasing technical sophistication of the modeling elements of scenarios and the continued simplicity of our understanding of the social origins, linkages, and implications of the narratives to which they are coupled.” This critique seems to be formulated mainly from the modeling side and out of academic ambition. The scientific credibility of combined results is perceived as being hampered due to the imbalance between the intuitive component (the storylines) and the analytical component with scientific ambitions. In response, the recommendation was formulated (e. g. Girod et al. 2009, Rounsevell/ Metzger 2010, Kemp-Benedict 2012) to use more systematic and formalized approaches to construct storylines (cf. also 3.3). In the following, two more difficulties of SAS-type approaches are detailed, as they are central to the focus of this study.

2.4.2 The traceability challenge

Integrated scenarios are challenged by what I would like to call issues of traceability. First, I identify traceability as a standard for scenario communication (2.4.2.1) and second, I discuss the traceability challenges inherent in combined approaches (2.4.2.2) (cf. also Kosow 2015).

2.4.2.1 A standard for scenario communication

Traceability of scenarios refers to what in the literature also is called transparency, explicitness, accessibility, documentation, or reproducibility. Even if there is little conceptual precision, literature shows that the idea of traceability is an agreed-upon and fundamental standard in futures research (Parson 2008, Grunwald 2011). With regard to scenarios, traceability is considered a substitute for participation during scenario construction (Parson 2008). The central idea is that traceability allows those actors, who have not been included in the production of scenarios, meaning the "recipient users" (Pulver/ VanDeveer 2009), to "make an informed choice, whether and how to use them" (Parson 2008: 4).[69] When engagement of users is not possible "[t]he only alternative is for developers to provide fully detailed and explicit accounts of scenarios underlying reasoning and assumptions […]."(ibid) and of embedded values.

This standard is "widely advocated" but rarely achieved (Parson 2008: 4) as it "requires such a 'traceable account' of how each scenario was produced including areas of weakness, low confidence and disagreement" (ibid.). This in turn requires the scenario builders to honestly reveal all ingredients and their mixture, according to Grunwald (2011), behind a scenario process; including the use of expert guesses, tacit knowledge, errors and detours, and to go beyond textbook presentations or idealized design descriptions (cf. van Asselt et al. 2010, Hinkel 2008). Thus, in sum, it is the traceability of both—of *scenario assumptions* and of the *scenario construction process*—that are seen as prerequisites enabling external recipient users to assess scenario quality and to decide whether and how to use these scenarios.

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69 Parson recommends: "When feasible, […] engagement ensures that scenarios are useful, and that assumptions and values embedded in them are understood and accepted by the users." When engagement of users is not possible, "how are users to understand what each scenario means, how closely its assumptions match their needs and how they might use it?" (Parson 2008:4).

2.4.2.2 Traceability of combined scenarios

In combined scenario approaches, both components, qualitative storylines as well as numerical model-based scenarios, are criticized for not being traceable.

With regard to the storylines, Alcamo himself (2008: 142) considers one of the key limits and challenges of SAS to be that qualitative storylines suffer from a lack of what he calls "*reproducibility*"[70], because they are based on "assumptions and mental models of storyline writers [that] remain unstated". As these assumptions are not transparent and not explicitly documented, the storylines are difficult or impossible to access, to criticize and to reproduce. In consequence, storylines are perceived as being unscientific (ibid).[71] In addition, the missing accessibility of the assumptions and mental models underlying qualitative storylines hinders the use by and the usability of these scenarios for external users (cf. Parson 2008: 4).

But numerical models—and the scenarios based on them—have issues with regard to transparency, explicitness and accessibility, too. Parson (2008: 5) and Grunwald (2011) warn that especially model- and simulation-based scenario studies do suggest scientific quality, but are very difficult to use by external users as these do not easily understand what is behind their results. Grunwald (2011) criticizes, with reference to model-based energy scenarios, the fact that the underlying models are often not public.[72] Van der Sluijs (2002) found that even publically accessible numerical models are based on hundreds of implicit (internal) assumptions, as well as modeling and simulation decisions that are often only partially documented and accessible to externals.[73] Thus, even those numerical simulation modeling results that are traceable in theory often are not so in practice—at least not to externals and to those who are not modeling experts.

The critiques of both components of integrated scenarios can be summed up in accusations from the one side that they are unscientific and non-transparent vs. accusations from the other side that they are black-boxed and technocratic. But considered jointly, *both* parts of combined scenario approach-

70 By the way, this is a term from a positivist perspective, not necessarily appropriate in the realms of scenario studies or post-normal science in general.

71 As a possible solution, Alcamo proposes to use visualizing techniques as causal loop diagrams or cognitive maps that depict system elements and, most important, the relations between these elements. He states „Once such a clear visual map is available for a storyline, then its basic content should be reconstructible." (Alcamo 2008: 142). The challenge of such visualizations then is that they easily become very complex, when picturing all interrelations. Therefore, research on new approaches is needed (cf. Alcamo 2008: 143).

72 Grunwald (2011: 827/828, my emphasis) pleads for "creating transparency in comparing them with respect to their premises and presuppositions and with respect to the consequences of different assumptions and methodological approaches as well," and for the "creation of transparency, namely concerning the knowledge components and their limits, concerning the uncertainties that are involved and that must be explicated (...) and concerning the exposure of the values, norms and even interests that are involved […]."

73 Especially models that are used for a long time tend to cover a lot of old implicit assumptions and decisions that nobody has full access to anymore.

es, namely storylines and numerical model-based scenarios, are *individually* challenged with regard to different issues in the domains of reproducibility, transparency, explicitness, access, documentation of scenario assumptions and scenario construction. In the following, I would like to refer to these using the term *scenario traceability*, see chapter 4.

The literature provides little insight into what happens to traceability, when both components come together. As one exception, Kemp-Benedict (2004) hopes that integrating approaches does foster traceability. He argues that mathematical modeling forces the narrative to clarify the definitions of its elements and of the interactions between these elements, which leads to more rigor and transparency. On the other hand, it seems plausible to assume that integrated scenarios do combine the difficulties of both components. In addition, the combination might add new complexities and muddling to the scenario construction process, as well as additional (e. g. not explicit ad hoc) assumptions.

2.4.3 The promise of consistency

The second quality challenge of integrated scenarios central in this study is their consistency. First, I identify consistency as a principle of scenario construction (2.4.3.1), and then I discuss consistency challenges of combined scenario approaches (cf. Kosow 2015) (2.4.3.2).

2.4.3.1 A principle of scenario construction

Consistency of scenarios is also referred to as coherence, plausibility, logic, realism, and compatibility (cf. also Tourki/ Keisler/ Linkov 2013: 7). Scenario literature shows that consistency is considered a *constitutive element* of scenarios, that is, an integral part of the definition of a scenario (e. g. EEA 2009: 6 and others).[74] At the same time, consistency is considered a fundamental *principle of scenarios construction and selection*; and therefore, in sum, a central quality and usability criterion.[75]

In my view, consistency is understood as a safeguard against the arbitrariness of scenarios. It is a substitute for empirical validation, which is not possible and not appropriate with regard to scenarios, because their subject is the future - and thus is not accessible in the present, and because they do not claim to be or to become true. As a scenario construction principle, consistency is a heuristic that forces the scenario builder to reflect, how bits and pieces are brought together to form scenarios (cf. also Tourki, Keisler, Linkov 2013: 7). Consistency is considered a necessary, but not sufficient, condition for a scenario to be plausible (cf. e. g. Kosow/ Gaßner 2008). Plausibility in turn is linked to the

74 A scenario is: ...”a *consistent* and plausible picture of a possible future reality that informs the main issues of a policy debate.”

75 See e. g. URL: http://forlearn.jrc.ec.europa.eu/guide/3_scoping/meth_scenario.htm

possibility and credibility of scenarios (cf. Selin 2011). In sum, the term consistency is used a lot but is mostly weakly and not consensually defined. [76]

Instead, different concepts, criteria and measures of consistency coexist. Van Asselt and colleagues (2010: 114) have shown that different understandings of consistency are circulating. These different understandings are linked to the different "temporal repertoires" (ibid) they are used: Consistency can mean being in line with historical trends and developments, when a "historic deterministic temporal repertoire" (ibid) is referred to. On the contrary, consistency can refer to the *internal consistency* of scenarios, when a "futurist difference temporal repertoire" is taken over. This means, that both understandings refer to current knowledge, but the first focuses on what we know about historical continuity, whereas the second focuses on what we know about the uncertainty of the future and the discontinuity of developments into the future. These different repertoires are linked to the different epistemological paradigms behind the various scenario schools, using either trend extrapolation or open thinking when proposing alternative futures (cf. section 2.2.).

In different scenario schools, different consistency *concepts* are applied: Mathematical models can be considered objectively to be internally consistent by virtue of their mathematical (causal) logic.[77] Storylines instead rely on holistic consistency filters, such as intuitive gut feelings, that are subjective consistency definitions.[78] More systematic qualitative scenario approaches use the consistency principle to combine future variants into comprehensive pictures and to select scenario samples (e. g. the so-called consistency analysis, CA). With this aim, different *formal* consistency algorithms and consistency *scales* have been developed. [79] The different consistency measures do apply different consistency *criteria*: CA uses the criterion of co-incidence or co-existence of factor developments. By contrast, CIB uses qualitative causal information considering the direction of influences between developments (cf. Weimer-Jehle 2009b, cf. also section 3.1.2).

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[76] Like many other criteria for scenario quality, see 2.1.2. Tourki, Keisler and Linkov 's summary on consistency illustrates this amalgam (2013: 7): "Consistency refers to the agreement or harmony between parts of a scenario. This quality is very important to the internal structure of any scenario. Indeed, logical consistency may be a necessary condition for a scenario to even be a possibility, without considering its probability (Scholz and Tietje 2002). Thus, a comprehensive consistency check of scenarios is desirable, especially when analysts use algorithms to generate scenarios by combining all projection variables. Almost all definitions of SA [scenario analysis] include this important notion. […] Adjectives such as 'plausible' or 'realistic' or 'reasonable' or 'compatible' are sometimes used in place of 'consistent.'"

[77] Nevertheless, in modeling, not all problems have pure analytical solutions. Especially simulation is often based on numerical approximation, as well.

[78] When it comes to storylines, authors advocate checking for narrative or communicative consistency (e. g. Gaßner 1992) by asking: Does the story make sense? Are assumptions for the future developments of different drivers and factors of a storyline or of one set of model input data in themselves logical and non-contradictory?

[79] An overview of different consistency *scales* (and different underlying consistency understandings) is presented in Tourki, Keisler and Linkov (2013).

Currently, the consistency principle is *criticized* as not being adequate for the representation of scenarios of complex adaptive systems, reasoning with the argumentations from transition research that inconsistencies point to dynamics and change.[80] This debate shifts the focus of attention towards (slightly, but not completely) inconsistent scenarios.

In sum, scenario consistency can be understood as an attempt to strive for academic rigor in the context of the supposed arbitrariness of the future openness of scenarios—and this concept is linked and associated with the academic tendencies in the scenario field.[81] We should keep in mind, too, that the term consistency often evokes the connotation of consistency with past developments, as van Asselt and colleagues have shown—even if it is applied in the paradigm of future openness.

2.4.3.2 Consistency of combined scenarios

Generally, authors of SAS-type approaches suggest that modeling and simulation are used to identify inconsistencies in the storylines (e. g. Alcamo 2008: 141): "The SAS approach […] can incorporate state-of-the-art computer models for generating numerical information about environmental changes and their driving forces and for checking the consistency of qualitative scenarios." This *promise of consistency* is repeated in the literature by many researchers, seemingly unchallenged, and in most cases without further explanation as to how it works (cf. e. g. Greeuw et al. 2000: 91, Gallopin/ Rijsberman 2000: 5, van Notten et al. 2003: 431, Alcamo/ Van Vuuren/ Ringler 2005: 148, Alcamo 2001: 28, 2008: 137, Kemp-Benedict 2004: 3). Kemp-Benedict (cf. 2004: 3) specifies that mathematical modeling exposes contradictions in mental models and that it can "provide a feel for the scope of possible outcomes within a narrative framework" (Kemp Benedict (2004: 3). But overall, literature is not very precise in defining what consistency means and how this "consistency check" (cf. Alcamo 2008 and others) can be carried out concretely and successfully in practice. These two issues are further elaborated in what follows.

The term consistency is not used in a precisely defined way in the context of combined scenario approaches. In descriptions of the SAS approach, different *levels* of consistency are referred to, without explicitly reflecting these. For instance, in a text on the methodology of the MEA (Alcamo/ van Vuuren/ Ringler 2005), the authors make allusions to what one can identify as at least four different *levels* of consistency, namely: consistency with current knowledge,[82] internal consistency of story-

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80 A summary of this critique can be found in O'Mahony (2014).

81 Possibly, some of the critique of the consistency concept in the scenario literature is also turned towards this scenario school more generally.

82 "By 'consistency' we mean that the storylines do not contain elements that are contradictory to current knowledge."

lines or of assumptions,[83] consistency between numerical models and storylines,[84] and finally consistency between (input and output data of) different numerical models.[85] These different levels are (implicitly) referred to by other authors, too (cf. e. g. Döll 2003/2004, Kemp-Benedict 2004).

In sum, there is not much conceptual clarity and explicitness with regard to the concept of scenario consistency in combined scenario approaches. This seems to be a heritage of scenario literature in general, where different consistency concepts, criteria and measures of consistency coexist, stemming from different perspectives on the future. In addition, qualitative and quantitative scenario approaches do bring with them different consistency criteria, namely intuitive vs. analytical ones (cf. above).

The second issue is that the promise of consistency seems difficult to keep. Scenario literature provides a conceptual argument and empirical evidence supporting this thesis. Conceptually, the SAS consistency check is limited to those parts of the storylines that are *covered by the numerical systems model, too* and is impossible to use on the (non-quantifiable) parts that fall out of the model's scope (Schweizer/ Kriegler 2012: 2). Kemp-Benedict agrees with Schweizer and Kriegler's critique, and adds that texts by SAS authors "provide little or no guidance to those responsible for the narratives beyond a dialogue with the model output" (Kemp-Benedict 20012: 1).

Empirically, the promise of consistency seems difficult to fulfill, as well. Volkery et al. (2008) report from their PRELUDE project that problems of consistency occurred on two levels.

- Consistency between different storylines was not achieved, as "assumptions […] appeared not to be consistent across the scenarios" (ibid: 474). This may have been due to the fact that each of the storylines, once generated, was further elaborated by separate groups.
- There were "problems of ensuring overall consistency between qualitative [storyline] assumptions and [corresponding] quantitative [model] input" (ibid: 747). This was potentially due to how difficult it was to quantify storylines "since stakeholders and modelers were not always able to find a common understanding" (ibid.) and as some of the assumptions were very difficult to quantify.

Still, this report is a rather a vague empirical hint, as the authors do not specify how they defined and measured consistency or the lack of it.

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83 "Both scenario types can be combined to develop internally consistent storylines assessed through quantification […]." "The development of scenario storylines facilitates internal consistency of different assumptions."

84 "During scenario development, several interactions were organized between storyline development and the modeling exercise in order to increase the consistency of the two approaches."

85 "These data were then used as input to the IMAGE land cover model that computed on a global grid the changes in agricultural land that are consistent with the agricultural production computed in IMPACT."

Further, more systematic and elaborated empirical hints are provided by Schweizer and Kriegler (2012): During an ex-post reconstruction of the IPCC SRES (see 2.3.3.), they analyzed the storylines with regard to their assumptions on interrelations between scenario factors. They did so with the help of the systematic CIB analysis (see chapter 3). They analyzed the degree to which the SRES sample would have looked different, if this method had been used—instead of the intuitive logics that were in fact used for this exercise. They discovered the following:

- The storylines of the SRES *vary widely with regard to their internal consistency*, taking the logic of the assumed interrelations between future developments as a criterion (Schweizer/ Kriegler 2012: 9).
- A considerable number of other scenarios (again based on the SRES assumptions on interrelations) that are *fully internally consistent, were absent from the SRES sample* (ibid.).

In sum, both empirical hints indicate that the consistency check as promised by SAS is not automatic. Looking at the designs of both the SRES as well as the PRELUDE study, possible *conditions* that have hindered the promise of consistency to be fulfilled (in addition to the fundamental conceptual limitation) seem to be the inadequate translation of storylines into numerical input data and missing resources for full and repeated iteration.

Overall, it remains unclear under what conditions and in what designs of combined scenario approaches the promise of consistency can be effectively fulfilled in practice—and for what levels and understandings of consistency.

2.5 Summary of research gaps

Futures studies are a field with an identity floating between the ideal of scientific rigor and the ambition of high practical usefulness. This tension is also reflected in the ongoing discussion on quality criteria of futures studies and scenarios. This debate also reveals that there is no consensus on how to deal with positivist vs. constructivist influences, claims and expectations. Instead, a large variety of different scenario approaches was developed from very intuitive and qualitative approaches to mathematical modeling—approaches with strongly divergent methodological and epistemological characteristics. In the field of environmental scenarios, for 15 years, scenario approaches of the Story and Simulation type have been established as state of the art. They combine storylines constructed in intuitive and participatory approaches with mathematical simulation models. They combine these different (methodological and epistemological) traditions and are characterized by a deep hybridity.

Although these approaches have plenty of appeal, they are also riddled with difficulties. First of all, combined approaches are only *weakly conceptualized*. There is a great variety of empirical designs, but not much conceptual work to reflect these and their effects. Overall, the scenario field is rather marked by many empirical applications and only little conceptual and theoretical reflection. Furthermore, the field is dominated by SAS- type approaches. Still, the SAS framework in its current form provides only limited methodological guidance for those designing and implementing their own—perhaps *new*—forms of combined and/or integrated scenario processes and methodologies. In addition, the review of combined scenario studies has shown that other forms of combined methodologies are possible, too, that go beyond the rather narrow frame of the SAS-type approach. Open questions are, e. g. what role can and should the two components play with regard to each other and for the overall scenario process? What type and degree of integration is possible and required, with what aims and by what means? Furthermore, combined and integrated scenarios require complex forms of cooperation between actors from different cultures—modelers, futurists, experts from various domains—and aim to integrate very diverse forms of knowledge (cf. Volkery et al. 2008). How can the social, cognitive and technical integration (cf. Becker et al. 2000) of integrated scenario methodologies be supported by their design?

Next to other difficulties of SAS-type approaches pointed out above, my research focuses on two major challenges when it comes to scenario quality. First of all, there are issues with regard the limits of what I call *scenario traceability*, namely issues of transparency, explicitness, access and reproducibility with regard to scenario assumptions on future developments and their interrelations, as well as with regard to scenario construction, selection and sampling. These issues are linked to the qualitative scenarios or storylines, but also to the traceability of mathematical models to externals and in addition also to the complex muddling through character of combined scenario methodologies. These issues of traceability are threatening the effective use of scenarios and the usefulness of scenarios for recipient and producer users. Second, there are conceptual arguments and empirical hints that the *promise* of *consistency* by SAS, namely that the numerical modeling makes it possible to carry out a consistency check of the qualitative storylines, is not easy to fulfill in the practice of combined approaches. Thus it is unclear, under what conditions the promise of consistency can be fulfilled in practice—and for what understandings and levels of consistency.

This leads to the next point since, in the current literature on (combined) scenario approaches, the issues of traceability and consistency are used in *conceptually imprecise* ways. With regard to traceability issues, it is unclear what elements of scenarios and scenario processes need to be traceable and by whom. With regard to consistency, different understandings of the term, as well as the levels of and criteria for its use are not clearly distinguished.

Finally, several authors proposed to *try out more formalized and systematic scenario approaches to* construct the storyline component. One specific proposal that is currently under discussion is to use cross-impact balance analysis (CIB) (Weimer-Jehle 2006) for developing the qualitative part of the combination. CIB and the expectations linked to its use within combined scenario approaches are presented in the next section (Chapter 3).

Chapter 3: State of research II: Cross-impact balance analysis

In the following chapter, I give an overview of the state of research on CIB. This is based on a review of the literature, supplemented by repeated informal exchanges with the developer of the method, Wolfgang Weimer-Jehle. I cluster the state of research on CIB from four different perspectives: First, I characterize CIB as a qualitative form of *systems analysis* with a specific methodic core (3.1). Second, I describe the use of CIB as a qualitative *scenario technique* in its different empirical designs (3.2). Third, I detail the current proposal to use CIB in *combination* with numerical modeling and simulation (3.3). Fourth, I give an overview of *empirical* applications of CIB in different fields of research (3.4). Finally, I sum up research gaps relevant for this study (3.5).

3.1 CIB—a form of qualitative systems analysis

In this section, I introduce the central method characteristics of CIB as a form of qualitative systems analysis. I present the method's core (3.1.1). I contrast CIB with neighboring approaches to qualitative systems analysis (3.1.2) and embed CIB in its historical, conceptual and epistemological backgrounds (3.1.3).

3.1.1 The method's core

The method's core is briefly described, mainly with reference to Weimer-Jehle, 2006, 2014a, Förster/ Weimer-Jehle 2003.[86] CIB is a systematic yet qualitative form of systems analysis. The method requires identifying system elements and exploring the interrelations between these (3.1.1.1). It results in a conceptual (impact network) model (3.1.1.3). The specific CIB balance algorithm is then used to identify internally consistent configurations of this network (3.1.1.2).

3.1.1.1 Building a qualitative impact network

In a CIB, a system is characterized as an impact network (Weimer-Jehle 2006). In a first step to delimit and define this impact network, relevant system elements are identified, selected and defined. In CIB they are named *descriptors* (A, B, C - N) (typically 10-20). These are "the most important factors which have a significant direct or indirect influence on the object of the examination" (Weimer-Jehle 2006: 228). The selection of descriptors delimits the scope of the systems analysis.

Second, for each descriptor, its (central) possible alternative developments, also called *variants* or states, are defined (Aa, Ab, Ac; Ba, Bb, Bc, … Na, Nb) (typically 2-4 per descriptor). Descriptors and variants are intended to represent the system under study and need to be clearly and selectively defined. The selection of variants delimits the variability of descriptor developments that is taken

[86] For more information, see the method website http://cross-impact.de.

into account. Descriptors are generally qualitatively defined; variants can be described by numerical values (quantitatively) or verbal statements (qualitatively). In terms of scales, nominal (e. g. red, green, blue) or ordinal (e. g. low, medium, high) scales or (not overlapping) numerical ranges (e. g. <0,5; 0,5><1,5; >1,5) can be used. Variants defined on different scales can be processed together in the same CIB (cf. Schweizer/ Kriegler 2012, Weimer-Jehle 2014a). D&V (descriptors and their variants) are contrasted in the form of a *matrix*, with all D&V listed in the lines and in the columns (for an example, see Figure 4). The number of D&V needs to be limited, because the effort to fill the matrix grows quadratically with their number (Weimer-Jehle 2006, 2014a).

Third, to consider the interactions of system elements, direct *impacts* between system elements are assessed. Each pair of variants is considered. The descriptor variants listed in the lines are understood as impact *sources* and the variants listed in the columns as impact *targets* (cf. Schweizer 2007). Every pair of variants is discussed with regard to the question of whether there is a direct influence of the one variant (in the line) on the other variant (in the column).[87] If an influence is seen as given, its direction (promoting or inhibiting influence?) is assessed. In addition, its strength *can* be assessed. It is important to note that only *direct* influences are specified. Indirect influences are established automatically by the CIB during the subsequent analysis.[88] Table 3 shows the scale that is frequently used to assess the *direction* (inhibiting or promoting) and the *strength* of influences between variants. The scale can be adapted to the specific requirements of each CIB exercise.[89]

Table 3: Typical scale to assess direct influences between descriptor variants in CIB (cf. Weimer-Jehle 2006)

-3	-2	-1	0	1	2	3
strongly restricting	restricting	weakly restricting	no influence	weakly promoting	promoting	strongly promoting

To establish the relative strength of different influences, the so-called *principle* of *compensation* (Weimer-Jehle 2006: 340) can be helpful: Two opposing influences on one variant are of equal strength, if their effects can compensate each other.[90] The diagonal of the cross-impact matrix generally is left empty.[91] Furthermore, CIB literature recommends applying a '*standardization convention'* (Weimer-Jehle 2014b: 2, Schweizer 2010: 68). This consists in ensuring that the sum of the

87 The question that has to be answered is, according to Weimer-Jehle (2006: 339): „If the only piece of information about the system is that descriptor X has the state x, will you evaluate this due to the direct influence of X on Y that descriptor Y has the state y (promoting influence, positive points assessed) or as a hint that descriptor Y has not the state y (restricting influence, negative points assessed)?"

88 If the rule of assessing only direct influences is not followed, indirect influences are double counted, which means their force is overestimated (Weimer-Jehle 2006: 339).

89 CIB does not require a scale with integer numbers (Weimer-Jehle 2006: 40).

90 If this is not the case, one of the effects should be rated higher.

91 It is possible to use the diagonal elements in order to represent self-enhancing developments.

impact assessments of one "judgement group" [92]—from one single descriptor variant on all alternative variants of another descriptor—sums up to zero (Weimer-Jehle 2006: 340).[93] When the matrix is completed, it represents the system under study in the form of an impact network. Figure 4 shows the full CIB matrix of a fictitious Somewhereland as an example.

3.1.1.2 Using the CIB balance algorithm

When the first three steps are completed, internally consistent configurations of an impact network can be determined through a *balance analysis*. A configuration is a bundle of variants and for each configuration, one variant per descriptor is chosen. The number of theoretically possible solutions of a matrix is the overall product of the number of variants for each descriptor. Not all of these configurations are meaningful and, in terms of CIB, internally consistent (cf. Weimer-Jehle 2006, 2014a, also for the next paragraphs). Therefore, CIB tests every theoretically possible constellation with the help of a specific balance algorithm to analyze its internal consistency. This test is based on the information on the impact relations between the descriptors that is stored in the matrix. The consistency of every combination of variants, meaning of each constellation, is determined through the influence balance of the impact network. The influence balances of the system are calculated, that is for each column, the influences are summed up: "[…] contrary influences of the same strengths compensate each other, contrary influences that vary in strength weaken each other by the prevalence of the stronger influence" (Weimer-Jehle 2006: 342). Internally consistent constellations are those combinations that are in accordance with the impact arguments of the impact network. For single configurations, this test can easily be done with pen and paper, see Figure 4:

a. Mark a test configuration in the matrix: Line by line, select one variant per descriptor (cf. the lines marked in grey). During this step, the variants are understood as influence *sources*.
b. Sum up the impact assessments of every selected variant per line (cf. the impact sums per variant in the balance line at the bottom of the matrix). During this step, the variants are understood as influence *targets*.
c. Compare per descriptor, if the highest sum per line corresponds to the variant that was assumed in the test constellation (marked by the arrows). If the double role of variants as sources and as targets does not contain contradictions, a consistent configuration is found (cf. Weimer-Jehle 2006: 340).

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92 To talk about the matrix, the following wording was established: A single cell is called a 'judgement cell'; a submatrix judging all influences of all variants of one descriptor on all variants of another descriptor is called a 'judgement section', a single line of a judgement section, i.e. all influences of one variant of a descriptor on all variants of another descriptor is called a 'judgement group' (cf. Weimer-Jehle 2006: 340).

93 The CIB balance algorithm does not require this standardization.

Figure 4: Example of a cross-impact balance matrix of the fictitious Somewhereland

My illustration, based on Weimer-Jehle/ Wassermann/ Kosow 2011.

…on / Direct impact of … („SOURCES“)	“TARGETS” G			FP			EP			DW		SC			V		
	p	e	s	cp	ri	cf	de	st	dy	ba	co	sp	te	ri	m	so	fa
government (G)																	
-"patriotic" (p)				-2	1	1	0	0	0	0	0	-2	1	1	0	0	0
-"economy first" (e)				2	1	-3	-2	-1	3	-2	2	0	0	0	2	-1	-1
-"social" (s)				0	0	0	0	2	-2	3	-3	2	-1	-1	-2	2	0
foreign policy (FP)																	
-cooperation (cp)	0	0	0				-2	1	1	0	0	0	0	0	0	0	0
-rivalry (ri)	0	0	0				0	1	-1	0	0	1	0	-1	0	0	0
-conflict (cf)	3	-1	-2				3	0	-3	0	0	3	-1	-2	-2	1	1
economic performance (EP)																	
-decreasing (de)	2	1	-3	0	0	0				-2	2	-3	1	2	0	0	0
-stagnant (st)	-1	2	-1	0	0	0				0	0	0	0	0	0	0	0
-dynamic (dy)	0	0	0	0	0	0				-2	2	3	-1	-2	0	0	0
distribution of wealth (DW)																	
-balanced (ba)	0	0	0	0	0	0	0	0	0			3	-1	-2	-2	1	1
-important contrasts (co)	0	-3	3	0	0	0	0	0	0			-3	1	2	2	-1	-1
social cohesion (SC)																	
-social peace (sp)	0	0	0	0	0	0	-2	-1	3	0	0				2	-1	-1
-tensions (te)	0	0	0	-1	0	1	1	1	-2	0	0				-1	0	1
-riots (ri)	2	-1	-1	-3	1	2	3	0	-3	0	0				-2	-1	3
values (V)																	
-merit (m)	0	3	-3	0	0	0	-3	0	3	-3	3	-2	1	1			
-solidarity (so)	1	-2	1	0	0	0	-1	2	-1	2	-2	2	-1	-1			
-family (fa)	0	0	0	0	0	0	-1	2	-1	1	-1	2	-1	-1			
		↓		↓					↓	↓		↓			↓		
balance	0	3	-3	2	1	-3	-9	-1	10	-7	7	4	-1	-3	2	-1	-1

If there is no correspondence, as in the example above regarding the descriptor on the *distribution of wealth*, the impact network contains the arguments for *why* the variant assumed in the test constellation is not consistent: Namely because in sum, there are stronger influences speaking for another variant. This check allows the meaningful interpretation of the reasons, why a network constellation fails to be consistent. In the example, overall strong arguments *against* the assumption of a balanced distribution of wealth are given through the government's economic orientation (-2), a dynamic economic development (-2) and a society oriented toward merit (-3). Because of the number of possible combinations, the consistency test of *all theoretically possible* constellations is carried out with the help of the CIB software program ScenarioWizard (see 3.2.2. below*).*[94] In the example of Somewhereland, 10 out of 486 possible configurations are fully internally consistent. CIB authors state that the number of completely consistent constellations of a CIB matrix tends to be rather small; thus the method is rather selective (cf. Weimer-Jehle 2006: 342).[95]

94 Freely available for download on URL:http://www.cross-impact.de/english/CIB_e_LgI.htm.

95 The set of internally constellations does not necessarily cover all predefined variants. It is possible that some variants do not appear in any of the consistent constellation and that other variants are part of eve-

3.1.1.3 CIB as a conceptual substitute

CIB is described by its author as a form of conceptual modeling, serving as a substitute when theories and numerical modeling are lacking.[96] Its application is proposed in the case of „complex but weakly structured systems" (Weimer-Jehle 2006: 336)—that means for systems, for which mathematical modeling is not possible or not appropriate. This can be the case either because theoretical foundations are lacking or because the knowledge is insufficient or not good enough that it can be reasonably quantified or „expressed trustworthily by a mathematical formula." CIB is proposed to analyze systems that are too complex for purely argumentative, verbal forms of systems analysis (Weimer-Jehle 2006: 335 ff.; cf. also Förster 2002: 91). As CIB deals with cases of limited systems knowledge, the results can be only "rough and rather qualitative" (Weimer-Jehle 2006: 336), and not very detailed.

CIB is intended to serve in multi- or interdisciplinary contexts that do not have theories on the interrelations of system elements at their disposal (Weimer-Jehle 2006: 336). A CIB impact network as stored in a CIB matrix can be understood as a *conceptual model,* and the process of carrying out a CIB analysis as a kind of *conceptual modeling* process. It supports those, who create the impact network, by making their mental models of the system explicit, and by doing so in a systematic form. Especially in some of the most recent publications (e. g. Weimer-Jehle 2014a), much emphasis is put on the job of CIB to reflect their users' mental maps of the system. This is supported by looking into the (simplified) mirror of these maps that is constructed by the network, which is composed of individual assumptions that the user has about the system. Internally consistent network constellations reflect the users' ideas on the system, ideas that he/she or they have fed into the matrix in the form of pairwise impact assessments. Results, in the form of internally consistent constellations, need then to be carefully considered and interpreted by discussing these impact assumptions once again. This requires that descriptors and their alternative developments be defined and documented so that those, who are involved into the process, agree on their definition. Typically, 'descriptor briefs' are written and circulated. Furthermore, impact assessments can, in addition to their numerical definition (-3 to +3) be stored in the form of textual justifications within the matrix, too, to be immediately accessible during the (joint) discussion of the impact network (cf. Weimer-Jehle 2014a).

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ry consistent solution (Weimer-Jehle 2006: 343)—but in different constellations for different reasons that lie within the impact logic of the network.

96 "Problems that allow a theory-based or empirically founded mathematical foundation should of course be analyzed with the help of computational models. Nevertheless, CIB analyses can make a valuable contribution here by offering a *preparatory environment analysis* or by promoting the analyst's understanding of the system through *an accompanying reflexive process."* (Weimer-Jehle 2006: 359, my emphasis).

3.1.2 Comparison to other approaches of qualitative systems analysis

To underline its specific properties, CIB is compared with neighboring approaches of qualitative systems analysis. Table 4 compares CIB with influence analysis (IA) (Vester 2002), consistency analysis (CA) (Rhyne 1974, Reibnitz 1991), MICMAC (Godet 2002) and cross-impact analysis (CIA) (e. g. Gordon/ Hayward 1968, Turoff 1972, Helmer 1981).[97]

CIB *shares* with these approaches that systems are characterized by qualitatively defined elements that are displayed in the form of a matrix. For instance, the definition of a list of factors and variants of a CIB does not differ from that of a CA. CIB also shares with the other approaches that interrelations between system elements are systematically considered and defined in a semi-formalized way. In addition, all approaches are based on expert judgements to define these interrelations. Furthermore, CIB shares with all other approaches that once a matrix of system elements and interrelations is established, some mathematical operation is carried out to learn about the systems characteristics. In addition, except for some forms of CIA, these approaches do not use probabilities. And, except for dynamic (or sequential) forms of CIA, these approaches provide rather static (or non-sequential) system representations.

In consequence, CIB also shares strengths and weaknesses with the other approaches. Their central strength is that they provide a systematic approach to fields that are difficult to capture in a mathematical way (cf. Weimer-Jehle 2006: 337). Also, they are formalized and thus essentially transparent—at least in the hands of professional users (cf. Mietzner/ Reger 2004: 54). Their central weakness is that the number of system elements (and variants) that can be taken into account is limited. This is necessary to keep the analysis operational—as every judgement needs to be made by experts in a meaningful way (cf. Weimer-Jehle 2006: 359). Consequently, only rough system representations containing little detail can be created. Finally, the quality of the analysis strongly depends on the quality of the expert input (cf. Weimer-Jehle 2006: 359).

The *specificities* of CIB become visible when it is compared with CA and CIA (cf. e. g. Weimer-Jehle 2009a and 2010b, unpublished manuscript). CIB and CA both aim to select meaningful bundles of variants (system constellations), [98] but they use different criteria: In CA matrices, information on the *co-incidence* of factors is stored: ‘Aa and Ba can occur together’. In CIB matrices, information on the *causal* relation between factors is stored.

[97] These specific neighboring approaches have been chosen for two reasons: First, they belong to the best known and most widely used approaches to qualitative systems analysis within the ‘formalized-systematic’ scenario communities (cf. section 2.2). Second, texts on CIB refer to them, either because of similarities and/or because of differences between CIB and these approaches.

[98] IA and MICMAC have the function of supporting the characterization (and selection) of factors.

Table 4: Comparison of CIB to neighboring approaches of qualitative systems analysis

	Influence analysis (IA)	**MICMAC**	**Consistency analysis (CA)**	**Cross-impact analysis (CIA)**[99]	**Cross impact balance (CIB)**
Central authors	Vester	Godet	Rhyne, Reibnitz	Gordon, Helmer, Turoff	Weimer-Jehle
Origin	70s	70s	70s	late 60s	2000
System elements	Factors	Factors	Factors and variants	Events	Descriptors and variants
Interrelations	Strength of direct impacts from every factor on all other factors "What impact does A have on B?"	Impact from each factor on all other factors (1 or 0)	Plausibility of coincidence of each pair of factor variants	Impact of (occurrence of) event A on probability of (occurrence of) event B	Direct impacts from every descriptor variant on all other descriptor variants
Indirect relations	Not considered	Considered	Not considered	Considered	Considered
Assessments	Based on literature and/or expert judgements				
Matrix	Full matrix, diagonal left empty	Full matrix, diagonal left empty	Matrix filled half, upper right half left empty	Full matrix	Full matrix, diagonal left empty
Central mathematical operation	Summing up assessments in lines and columns (active and passive sums)	Matrix multiplication	Elimination of constellations containing pair-inconsistencies	Analyzing changes in event probabilities, taking into account their mutual consequences	Balance analysis, calculation of consistent constellations with the CIB balance algorithm
Consistency criterion	/	/	Co-incidence	Causality	Causality
Function in scenario process	Factor characterization (and selection) ('system grid')	Factor characterization (and selection)	Scenario bundling (and sampling)	Exploring event probabilities (through calculation of event sequences)	Scenario bundling (and sampling)
System representation	Static	Static	Static	Dynamic	Static
Formalization	Low	Rather high	Rather low	High	Moderate
Comprehensibility, transparency	High, easily understandable and easy to communicate (my assessment)	Medium (myassessment)	High, easily understandable and easy to communicate (Weimer-Jehle 2009a)	Less simple, not generally understandable (cf. Mietzner/ Reger 2004)	"Still generally understandable" (Weimer-Jehle 2009a)

99 In this overview, a probabilistic type of CIA is assumed, reasoning in terms of trends. Please note that a plethora of different CIA approaches exists, e. g. deterministic ones vs. those using various types of probability (causal, conditional, joint) and those considering system elements in the form of trend, events or trends and events (cf. Weimer-Jehle 2006: 337 ff. and Weimer-Jehle 2010b unpublished manuscript).

When Aa and Ba occur together, this can have several different reasons, namely: “Aa promotes Ba” or “Ba promotes Aa” or “Aa and Ba mutually promote each other” or “Aa and Ba are both consequences of Cb”. This information is not given in a CA and therefore, system constellations considered ‘consistent’ in CA are not always meaningful and free of internal contradictions. Weimer-Jehle (2009a) writes that CA has a “local” and CIB a “global” consistency concept. In CA, indirect effects can play a role in co-incidence assessments. In CIB, indirect effects are systematically taken into account through the analysis. The effort to carry out a CIB is higher, as a higher amount of information needs to be collected. This is done by filling the matrix fully by considering all possible impacts from all descriptor variants on all other descriptor variants—whereas in CA, only half of the matrix needs to be filled (Weimer-Jehle 2009a). Also, whereas CA is a very easy, well-established approach and simple to use and to understand, CIB is less easy to understand but, in the words of Weimer-Jehle (2009a), at least still ”generally understandable.”

The causal information generated and processed during a CIB is comparable to information in CIA. But in contrast to CIA, CIB does not require that the experts assess the system consequences. Furthermore, CIB does not reason in terms of probabilities and is rather non-sequential (cf. Weimer-Jehle 2010b, unpublished manuscript). Finally, the mathematical formalization of CIB is much lower than that of CIA, as its central operation can be traced with pen and paper.[100] Therefore, authors hope that CIB is understandable, even for people without a specific mathematical focus, meaning for those who are no experts in the method (Weimer-Jehle 2006).

In sum, the specific features of CIB are: First, to consider variants of system elements in their double role as influencing factors and as factors receiving influence; second, to analyze the internal consistency of system constellations based on this causal impact information using the specific CIB balance algorithm. Third, CIB has a medium degree of formalization. For individual system constellations, the balance calculation can be carried out with pen and paper.

3.1.3 Historical, conceptual and epistemological backgrounds

The CIB approach was under development since the year 2000 by the Center of Technology Assessment, Baden-Württemberg.[101] The developer of the approach, Wolfgang Weimer-Jehle, is a physicist, who is also trained in systems analysis. He is currently the scientific executive director at ZIRIUS, Research Center for Interdisciplinary Risk and Innovation Studies (until 2012: ZIRN) at the University of Stuttgart, which is an interdisciplinary environment emphasizing the social sciences. The basic motivation that led to the development of CIB was a perceived gap between highly formalized mathemat-

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[100] CIB differs from CI “due to an especially good relation between its method transparency and its variety of statements” (Weimer-Jehle 2006: 338).

[101] In German: Akademie für Technikfolgenabschätzung Baden-Württemberg.

ical approaches for energy scenarios on the one hand and very discursive, unsystematic and incomplete approaches to qualitative scenarios on the other. On the occasion of the liberalization of the European energy markets, there was a call for a new method that would allow for a systems analysis that included qualitative dimensions. Initially, the idea to use classical CIA was discussed. But due to its highly mathematical character, CIA did not seem to fit the requirement to be transparent and to be easily usable in discursive communication processes dealing with (potentially) diverging expert assessments. Therefore, an easier and more intuitive algorithm was sought.[102] The new CIB approach was developed and then tested in the course of the Forum for Energy Models and Energy-Economic Systems Analysis.[103]

The CIB approach is a hybrid approach that draws on diverse conceptual and epistemological sources.[104] At first sight, CIB is a specific new variant of classical CIA—a qualitative, static and non-probabilistic one (cf. Weimer-Jehle 2010, unpublished manuscript), building on a fairly technical and apparently positivist approach to soft systems thinking. It has considerable mathematical depth: The underlying theoretical basis of CIB is mathematical systems theory. Mathematically, CIB matrices correspond to time-varying pair-force systems that adjust in force fields along trajectories. Consistent states of CIB matrices correspond to quasi stationary equilibrium states of these systems. Mathematically speaking, CIB is an approximation to search for equilibrium states in pair-force systems. This has implications, e. g. with regard to the rather static conceptualization of systems (for details cf. Weimer-Jehle 2006, 2008). In the language of game theory, internally consistent solutions of a CIB matrix correspond to Nash equilibria (Weimer-Jehle 2015, unpublished manuscript).[105]

At the same time, CIB clearly belongs to the field of qualitative systems and scenario analysis which in turn is based on rather constructivist premises. Also, it is strongly influenced by ideas of expert- and stakeholder participation and of transparent discourses in inter- and transdisciplinary research. It focuses on developing a shared understanding of the system under study, or at least of the reasons for dissent (Förster 2002,[106] Weimer-Jehle 2006). Weimer-Jehle (2014a) emphasizes that a CIB system model does not claim to represent reality, but to represent the system perception of its participants. Finally, CIB was, from its origin, motivated by the idea to combine qualitative and quantitative approaches of systems analysis (e. g. Förster 2002, Weimer-Jehle 2006). In sum, the CIB method con-

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102 Personal communication Wolfgang Weimer-Jehle.

103 In German: Forum für Energiemodelle und energiewirtschaftliche Systemanalyse, FEES.

104 I consider that is important to know about these sources to fully understand the method’s characteristics– and the expectations related to it. Whereas the first publication of CIB (e. g. Weimer-Jehle 2006), was mainly directed at the CIA communities, stressed its mathematical foundations and had a technical, almost *positivist* perspective, younger publications put more emphasis on the discursive and qualitative character of the method and its rather *constructivist* perspective (e. g. Weimer-Jehle 2014a).

105 Also, CIB can be conceptualized as a Turing machine (Weimer-Jehle 2009b).

106 Förster (2002: 113, my translation): „The cross impact approach [CIB] is not exact science, but a systematic approach for a comprehensive reflection of one’s own understanding of a system.”

tains inbuilt tensions between these—sometimes contradictory—conceptual backgrounds and epistemological perspectives.

3.2 Using CIB as a qualitative scenario technique

3.2.1 Basic idea

The qualitative systems analysis CIB can be used as a qualitative scenario technique. With that aim, descriptors are defined as important factors for the future development of the system, their alternative developments as alternative future developments. The CIB matrix represents the interrelations between these possible future system developments. Finally and centrally, internally consistent network constellations are considered alternative future scenarios.

CIB as a scenario technique falls into the group of systematic and semi-formalized scenario techniques—but clearly recognizes its subjective elements (e. g. its foundation on expert judgements) (e. g. Weimer-Jehle 2014a). The CIB balance algorithm can be used to analyze the consistency of given scenarios but also to systematically scan the so called scenario space for all internally consistent scenarios. Thus, CIB supports the construction of individual scenarios and scenario sampling.

3.2.2 Different designs

Scenario processes using CIB can be designed in various ways with regard to data collection, data analysis and data presentation.

With regard to *data collection*, Weimer-Jehle and colleagues (2016: 959) emphasize:„[t]he preparation of the cross-impact matrix is a genuinely interdisciplinary task and must be realized within a multi-discipline work setting, using participatory approaches to gather expert judgments, either individually, in group exercises, or through desk research.” Users of the CIB approach need to decide what data they want to include (e. g. on what scales and from what sources) and what actors to include at what time in the process. Lists of D&V are established either through desk research, expert surveys or both (e. g. Weimer-Jehle/ Deuschle/ Rehaag 2012).The size of matrices that are produced during CIB processes varies considerably. This very much depends on the available resources and the required level of detail. Impact assessments are gathered through (more or less structured) surveys with individual experts of various disciplines (e. g. Schweizer/ O’Neill 2014) or during workshop situations (e. g. Weimer-Jehle/ Deuschle/ Rehaag 2012).

With regard to *data analysis,* the balance analysis is the central analytic tool of CIB. Users can chose, the ‘consistency level’, this means, they can decide whether they accept only fully internally consistent scenarios or whether they also want to consider slightly internally inconsistent solutions of impact networks for further interpretation. In addition, CIB matrices allow other forms of analysis, such as influence analysis for a first characterization of descriptors; analysis not only of stationary but also of cyclical solutions for the impact network; scenario succession to consider scenario dynamics as well as forms of correlation, interdependence and intervention analysis (for a detailed example of the variety of forms of analysis cf. Weimer-Jehle/ Prehofer/ Kosow 2013, Weimer-Jehle 2006, Renn et al. 2009). Many of these forms of analysis are supported by the CIB scenario software, ScenarioWizard.[107]

The scenario software also supports different forms of *data presentation* through (semi-)automatic output of, e. g., a system grid; a so-called 'scenario table' or scenario tree (in CIB language: tableau) for a quick overview of the different network constellations (e. g. Figure 19 in 6.1.2.4 or Annex BB) as well as the so-called 'scenario-protocol' that automatically compiles all textual information regarding selected (consistent or inconsistent) solutions for the impact network, comprising textual justifications of impact assessments as well as the visualization of the balance logic behind every descriptor variant in the form of an 'impact diagra'm (e. g. Figure 20 in 6.1.2.4 or Annex GG). These protocols are intended to support the effort to understand and to explain why the content of a specific scenario is considered internally consistent or not, based on the impact assessments stored in the matrix.

Weimer-Jehle and colleagues (2016: 960) recognize: "The output [of a CIB] is a set of raw scenarios, which still needs refinement, interpretation of the inner scenario logic, and verbally formulated stories." Scenarios derived from CIB vary considerably with regard to their literary, visual or formal character and length, depending on the targeted audiences and the intended use of the scenarios.

3.3 The current proposal to use CIB in combination with numerical modeling and simulation

The current scenario literature proposes to use CIB in combination with numerical simulation and modeling. In what follows, this proposal and the expectations linked to it are introduced (cf. Weimer-Jehle et al. 2016, also for the next paragraphs).

In the field of climate change research, critical discussion of the current practice of combined scenario approaches (of the SAS type) is ongoing, and ways to take it forward are under development. In response to the perceived weaknesses of the storyline part in approaches of the SAS type (cf. e. g. Garb et al. 2008), the use of more systematic and formalized approaches to construct storylines was recommended (e. g. Girod et al. 2009, Rounsevell/ Metzger 2010, Kemp-Benedict 2012).

Currently, CIB is proposed as just such a potential alternative or complement for developing the qualitative part of combined scenario approaches (e. g. Schweizer/ Kriegler 2012, Kemp-Benedict 2012).

[107] For more information, please see the software and its manual, as well as the method guidelines 1-4, available for download on www.cross-impact.de.

This new combined approach was introduced under the label of ‘context scenarios’, emphasizing the potential role of CIB to provide societal context assumptions to (energy) modeling and simulation (Weimer-Jehle/ Prehofer/ Vögele 2013, Weimer-Jehle et al. 2016); and under the label of ‘CIBAS’, introducing the approach as a new form of combined scenario approach for environmental research (Kosow 2011).

CIB was originally developed to be used jointly with numerical modeling in the field of energy scenarios (cf. 3.1.1 above). This means that this combination was intended from the start. But at the time this study began, CIB was in frequent use as a stand-alone method (see section 3.4), and only a single combined application had been empirically realized, namely the one documented by Förster 2002.[108]

What is expected from the use of CIB within combined scenario approaches? Basically, CIB is expected to counter some of the perceived weaknesses of the more intuitive approaches to the qualitative scenario parts (cf. chapter 2). Table 5 compares CIB to Intuitive Logics (IL) (Wack 1985a, b, Huss/ Honton 1987), which is the approach predominantly used for storylines in combined scenario approaches (type SAS) from a scenario-analysis perspective.

Ideally, IL is predominantly based on the intuitive, and CIB on the analytical mode of thought (cf. Trutnevyte/ Stauffacher/ Scholz 2011). But, depending on their design, both approaches do also mix these perspectives: When IL is used to construct *exploratory* scenarios, the definition of system elements can occur in a rather systematic and analytic way, too (e. g. GEO-4)—and CIB also relies on expert intuition, e. g. to define D&V, to assess impacts, and finally to interpret network constellations and to choose and define scenario samples. From a philosophy of science perspective, Lloyd and Schweizer (2014) have compared CIB with IL. They argue that CIB supports the "objectivity" of scenario construction compared with IL on several dimensions.[109]

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108 Förster (2002) reports that CIB was used to construct four qualitative scenarios on the liberalization of the energy market in Germany (i.e. on the national level). These were downscaled and used to model the energy system of Baden-Württemberg with the so-called E^3Net program. Some of the CIB descriptors were used as model input, some were expressed through model outputs.

109 Lloyd/ Schweizer (2014): "From a purely philosophical perspective, the CIB method clearly promotes an increase of objectivity—under several definitions, (1) public, (2) detached, (3) unbiased, and (6) procedurally objective—when contrasted with the Intuitive Logics approaches. Additionally, by its procedures, the CIB method invites the incorporation of obscure interdisciplinary information and retains this information in the scenario building process, while Intuitive Logics is prone to losing it through unconscious cognitive biases as well as groupthink. Moreover, through its public display of disaggregated judgments, CIB is more responsive to improvements in data or theory. In our view, these qualities of CIB also enhance (7) structural objectivity over Intuitive Logics". The authors do struggle with the inbuilt tensions of CIB, as they also go to the defense of IL and ask whether, in the realm of scenarios, *objectivity* is even an appropriate criterion.

Table 5: Comparison of Intuitive Logics (IL) and CIB

Adapted and extended from Kosow 2011, Trutnevyte/ Stauffacher/ Scholz 2011.

Dimension	**IL**	**CIB**
Understanding of the future	Because of uncertainty and complexity, alternative futures are possible (forecast non suitable).	
Scenario approach	Qualitative	
Type of scenario technique	Creative-narrative, holistic	Systematic and semi-formalized
Principal mode of thought	Intuitive	Analytical
Typical participants	Decision maker, stakeholder, experts and laypeople	Experts and stakeholder rather than laypeople
Definition of system elements	Qualitative, textual; detail, nuance and flexibility possible	Qualitative, textual; strict selection of D&V
Characterization of interrelations	Selective, textual	Systematic, semi-formalized
Type of underlying model	Relies on implicit mental models	Explicit conceptual model (impact net-work)
Identification and definition of scenario factors and variants	Varies from intuitive (and less transparent) to systematic.	Explicit, systematic, transparent
Bundling (composition of individ-ual scenarios)	Intuitive, creative bundling (with detail and nuance)	Systematic and transparent bundling as based on the criterion of internal con-sistency.
Selection of scenarios (sampling)	*Selective* sampling, often using the scenario-axes.	*Comprehensive* and open sampling considering all plausible constellations.
Typical type of scenarios	Normative or exploratory	Exploratory (normative.
Temporal orientation	Sequential or non-sequential	(Rather) non-sequential (static)

In sum, two central expectations are linked to the use of CIB in combination with modeling and simu-lation: First, the qualitative scenario parts are expected to be *transparent and replicable*. Biases oc-curring in intuitive closed shop settings are expected to be reduced (Lloyd/ Schweizer 2014, my emphasis): "Because of its systematic, disaggregated, and public procedure, the CIB method has the advantage of making storyline scenarios *replicable* as well as limiting the known cognitive and social biases, especially groupthink, involved in making the interdisciplinary judgments involved in scenario building."[110] In addition, CIB forces its users to reveal assumptions about societal developments and model frameworks: "An additional benefit [...] is that the qualitative part of SAS is strengthened by improvements in traceability and objectivity (Lloyd/ Schweizer 2014), because any assumptions relat-ing to complex societal developments and the framework for the model are explicitly addressed and revealed." (Weimer-Jehle et al. 2016: 964). Discursive[111] and interdisciplinary group learning and knowledge integration[112] effects attributed to CIB are expected to support this effect (Weimer-Jehle

110 Note the positivist vocabulary, e. g. the use of the term “replicable” (ibid.)

111 *Discursive* benefits expected from CIB are that experts have to make the reasons for their judgements explicit (Weimer-Jehle 2006: 359); and that differences between judgments (dissent) become visible and can be discussed

112 The effects of inter- and transdisciplinary learning and knowledge integration, expected from CIB, are the creation of new perspectives on the system and a shared understanding of the system under study (Wei-mer-Jehle 2006: 359). “It makes possible the systematic integration of quantifiable parts of correlations,

et al. 2016: 964): "By systematically developing traceable and transparent impact networks (in an impact matrix) for the system under consideration, storyline revisions and updates become easier, or even simply possible." Underlying this expectation is the supposition that CIB is fairly easily understood by a wide group of users (Weimer-Jehle 2006: 359): "The simplicity of its fundamental logic means high transparency even for participants without deep mathematical training and so promotes the acceptance of the method and the results."

Second, CIB is expected to ensure the *internal consistency* of qualitative scenario parts, since: "[…] by using the more systematic CIB-based approach, we are better able to ensure input data set consistency and plausibility." (Weimer-Jehle et al .2016: 964). This means the internal consistency of the qualitative scenarios is ensured by CIB itself and thus does not require a consistency check through the numerical models. Furthermore, the use of the CIB consistency check is expected to support the inclusion of non-intuitive scenarios into the scenario sample:

> Additionally, [CIB] tests very large numbers of variable combinations for consistency. This not only produces the desired information concerning relative consistency but uncovers unusual and surprising scenario combinations, regardless of their perceived likelihood. This means that CIB can highlight internally consistent scenarios that, for whatever reason, are *perceived* as unlikely but have high impact. (Llyod/ Schweizer 2014)

In sum, some researchers expect that the use of CIB within combined scenario approaches will enhance the traceability and consistency of combined scenarios. This expectation will be further discussed in the course of this study.

3.4 Empirical experiences with CIB

Overall, there is already considerable empirical experience with CIB as a stand-alone approach—using it either as a form of qualitative systems analysis or as a qualitative scenario technique. Central applications of CIB are summarized in Table 6. For a comprehensive bibliography, see URL: http://cross-impact.de/english/CIB_e_Pub.htm. Currently, new empirical applications trying out a use of CIB *in combination* with numerical modeling and simulation are implemented in the fields of environmental research. This PhD study focuses on the application of CIB in combination with numerical modeling and simulation in the fields of sustainability and environmental research. Therefore, the two very first empirical applications in these fields serve as the two case studies of this thesis. More recently, combined applications have been tried out in the field of energy and climate scenarios, too—some documented by Hansen and colleagues (2014)[113] and some by Ruth and col-

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as far as they are known, and by that provides an integrative analytical basis for mathematizable and non mathematizable problem parts."(Weimer-Jehle 2006: 359).

113 Hansen et al. used CIB to develop coupled qualitative scenarios of the future household heat consumption on a global, national and sectoral scale, providing multi-level contexts for sectoral modeling.

leagues (2015).[114] But neither group reports much on methodological or conceptual issues concerning the combination. Further combined applications dealing with the German energy transition—ones taking more consideration of concept and method—are currently ongoing (cf. Weimer-Jehle et al. 2016 and Prehofer et al., forthcoming).

Table 6: Examples of the three types of applications of CIB, sorted by issues

Issue	**Qualitative systems analysis**	**Qualitative scenario technique**	**Combination with numerical modeling and simulation**
Energy		Vögele 2013 Jenssen/ Weimer-Jehle 2012	Förster 2002 Hansen et al. 2014 Prehofer et al. (forthcoming) Weimer-Jehle et al. 2016
Climate and climate change effects		Schweizer/ Kriegler 2012 Schweizer/ O'Neill 2014 Wachsmuth 2013	Ruth et al. 2015
Environment and sustainability (e. g. waste, water, land use etc.)	Renn et al. 2009 Uraiwong 2013	Kemp-Benedict /de Jong/ Pacheco 2014 Saner et al. 2012 Meylan/ Seidl/ Spoerri 2013	Weimer-Jehle/ Wassermann/ Kosow 2011 *(➔ see case study I)* Kosow/Schütze/ Leon 2013 *(➔ see case study II)*
Health	Weimer-Jehle/ Deuschle/ Rehaag 2012	Aschenbrücker/ Löscher/ Troppens 2013	
Innovation and Technology	Fuchs et al. 2008	Schneider/ Gill 2015	

3.5 Summary of research gaps

CIB is a systematic, semi-formalized yet qualitative form of systems analysis with specific properties: It is based on expert judgments on the direction and strength of mutual influences of alternative developments of system elements. It uses a balance algorithm to determine internally consistent network constellations. It has a specific causal understanding of consistency. Its consistency calculations are expected to be traceable by laypeople without particularly strong mathematical skills and by using pen and paper. CIB was applied as a qualitative scenario technique and stand-alone method in various fields. It has a hybrid conceptual background, bringing positivist ideas from the fields of mathematics and cross-impact analysis together with constructivist premises of interdisciplinary, discursive, participatory and future-oriented research. In energy and climate research, researchers have proposed to use CIB in combination with modeling and simulation. This proposal is based on the expectation that CIB could support the traceability and consistency of the qualitative aspect of integrated scenarios.

114 Ruth et al. used CIB to develop qualitative "framing scenarios" for regional energy, climate and agriculture modeling, exploring the energy transition of Northwest Germany.

From the perspective of CIB method research, two research gaps are relevant to this study. These add to the gaps already identified in the previous chapter. The use of CIB in combination with modeling and simulation has not yet been systematically empirically tested, nor has it been fully conceptually though through. A single initial empirical application of the combination was realized in the field of energy scenarios in the year 2000. Further applications had been carried out in the field of socio-environmental scenarios when this PhD project began in 2010, which meant I could make use of them for this study. Overall, we do not know yet, whether and in what way CIB does have the expected effects when used within combined scenario methodologies. The central open questions concern the function of CIB in combination with mathematical modeling and simulation in the construction of socio-environmental scenarios; the forms of its combination that are possible; the effects of CIB on traceability and consistency; and what other, perhaps unintended, effects it may have.

In addition, despite the numerous empirical experiences in various fields and the varieties of designs applied, there has not been any systematic empirical study yet, asking different CIB *users* for their experiences with the approach or comparing different designs. Instead, there is only anecdotal evidence of participant perceptions as well as reports by CIB users on these aspects.

To explore these open questions, I have constructed a conceptual framework (Chapter 4) to guide the analysis of and reflection on two empirical cases, using CIB in combination with numerical modeling and simulation (CIB&S) in the form of exploratory case studies (Chapters 5-8).

Chapter 4: Conceptual framework

In the following chapter, the conceptual framework of this study is presented. It draws from the literature review on combined scenario approaches and on CIB. This framework has two functions: It is used to develop conceptual ideas on the forms and effects of CIB&S, and to focus and pre-structure the data collection and analysis of the two empirical case studies.

I start with a conceptualization and contextualization of combined scenario processes as 'transdisciplinary methodologies' consisting of an interplay of multiple elements, namely actors, methods and data that influence the various activities in a scenario process (4.1). Second, I derive several analytical concepts from the foregoing literature review: To analytically divide CIB&S processes into their activities, a process model is developed. To characterize different forms of the combination of CIB with numerical models, central dimensions are defined (4.2). Third, to assess combined scenario processes and products, working definitions of scenario traceability and scenario consistency are developed (4.3). Fourth, I explain the approach of this study looking for different types of effects of CIB within complex and idiosyncratic scenario methodologies (4.4). Finally, I give an overview of the scope of the study, refine the research questions for the empirical analysis and detail my expectations (4.5).

4.1 Conceptual basis: Analyzing CIB&S methodologies

In this section, I present the conceptual basis of the analysis, namely a framework to analyze transdisciplinary methodologies (4.1.1). Then I transfer it to the analysis of the use of CIB within combined scenario processes (4.1.2).

4.1.1 A framework for analyzing transdisciplinary methodologies

In this section, I present the conceptual basis of the analysis, critically discuss it, and finally justify its selection.

Hinkel (2008: 46 ff.) proposes a graphical "framework for analyzing methodologies." He has developed this framework in the field of transdisciplinary environmental research, specifically for research communities doing integrated assessments and vulnerability assessments. Its objective is to support the quick but precise presentation and comparison of different project designs and processes. The approach is based on a distinction between methods and methodologies:

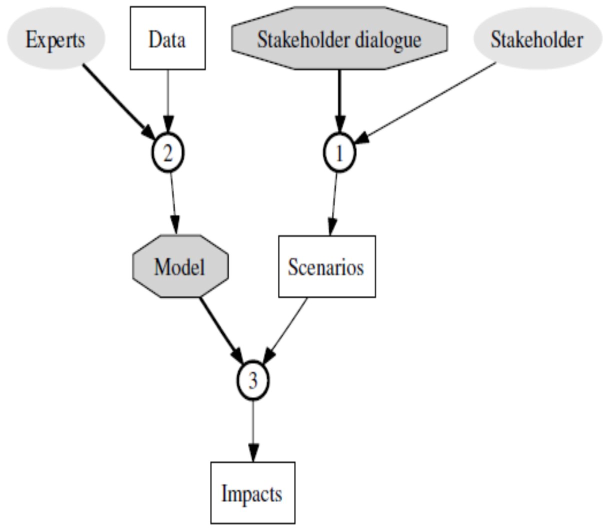
- "A <u>method</u> is a specification of a process that makes the process reproducible by others and applicable to other cases, [neither of these being generally] possible for a methodology of a transdisciplinary assessment" (Hinkel 2008: 45, my underlining).
- "In the context of transdisciplinary assessments, the specific configuration of methods, data and people involved in solving a problem is usually called the *<u>methodology</u>*, *integrated meth-*

> *odology* or *methodological approach* of the assessment" (Hinkel 2008: 44, Hinkel's emphasis, my underlining).

In line with this rather general definition of method by Hinkel, this study understands a method as a (set of) rule(s) that defines, how to do something in a way that is both reproducible and transferable to other cases, that is the *nomothetic* element within a research process. A methodology, then, is the unique, *idiosyncratic* constellation of different elements, including their interplay in practice.

Figure 5: Example of the visual presentation of a methodology

Source: Hinkel 2008: 48.



Example of a methodology. The octagons represent methods, the rectangles data, the ovals actors and the numbered circles activities.

Figure 5 above shows a depiction by Hinkel (2008) of a combined scenario methodology. To analyze methodologies, their specific configurations are revealed by analytically dividing research processes into *activities*. Then, on each activity, the specific influences are identified, namely influences by *methods*, *data* ("in the widest sense, which includes observed or measured data, as well as derived data" [Hinkel 2008: 47]), and *actors* ("people involved in the application […] of the methodology, that is the scientific experts or the stakeholders," [ibid: 46]). Hinkel assumes that activities are always driven either by actors or by methods; and that method-driven activities are reproducible (ibid: 47).[115] Possible *outputs* of each activity are data or methods (ibid.47). The specific configuration of a

[115] I decided to conceptualize activities less strictly into *mainly* actor- or *mainly* method-driven ones. This is because methods are chosen and applied by actors. The initial decision to use a method is itself actor-driven, which means that the choice of a method might lead to path dependencies that limit the impact of the actors in favor of the impact of the methods. Hinkel further distinguishes between subjective and objective activities, with objective activities having a deterministic outcome. Hinkel himself criticizes the fact that this definition is difficult and I decided not to use it in this study.

methodology is depicted by a graph linked through the outputs of an activity that are used as input for the next activity. It discerns four types of nodes: data, methods, actors and activities.

Hinkel warns that the application of the framework is not trivial (2008: 59). First, it requires a considerable amount of *information* on the process. Second, there is the danger of mixing three different views on the methodology of a project:“(i) the methodology originally designed at the beginning […], (ii) the methodology actually applied […], (iii) the methodology to be applied when one would repeat the assessment” (Hinkel 2008: 59).

Third, detail and granularity are a matter of choice, as “activities can be decomposed further into sub-activities or aggregated into super-activities” (Hinkel 2008: 59). The level of granularity has to be chosen as a function of the aim of the analytical decomposition of the methodology.

From my perspective, what is most difficult with this framework, is that the categories are very broad but not completely selective. Behind the use of methods, there are always actors deciding about their use and their individual application. The same holds true for data, e. g. in the form of expert judgements, which do not exist independently of the actors behind—and again, actors decide what data are fed into a process. At the same time, the framework is rather *weak from a social science perspective*, as actors do act—and they do so not 100% rationally—with specific aims, interests and resources and are themselves embedded in structural contexts such as institutions, organizations, paradigms and cultures. Furthermore, the framework still needs to show, whether it is appropriate to go beyond textbook presentations of methodologies by depicting changes and detours as well. But I assume that this should be possible through the granularity of the respective presentation. Finally, it is unclear, whether and how time or timing (not explicitly introduced by Hinkel) can be appropriately presented within the framework—and whether the (not) parallel organization of branches of the graph are sufficient for this aim.

Nevertheless, I choose to try out this conceptual basis to explore methodologies using CIB in combination with modeling and simulation for several reasons. First, because of the lack of alternatives,[116] second because of its simplicity, third because of its visual informatics character that I expect is expected to match with ideas used in (environmental) modeling communities, and fourth, because of its flexibility in the capacity to depict either planned, effectively carried out or recommended methodologies. Finally, I choose it because it allows me not only to *describe* CIB&S methodologies but also to support the tracing and interpretation of effects of specific elements of a methodology (see 4.4).

[116] When I started this study, this approach was to my best knowledge the only one to analyze methodologies in transdisciplinary research in this way.

4.1.2 Analyzing CIB&S methodologies

In this section, the framework is transferred to the issue of this study, namely the analysis of CIB&S methodologies. Even if the framework by Hinkel had been developed specifically to the field of vulnerability assessment, "it is not limited to this field and can be applied to other sorts of transdisciplinary research" (Hinkel 2008: 43 ff.) and "the application to other fields of transdisciplinary research like sustainability or future research, will be explored" (Hinkel 2008: 60). Thus, I assume that it is appropriate to apply it to scenario processes in general and, more specifically, to processes using CIB in combination with numerical modeling and simulation.

In this study, following Hinkel (2008), scenario construction processes are understood as scenario construction methodologies, meaning a *specific configuration of methods, data and actors involved in constructing scenarios*. Scenario construction processes combining CIB with numerical modeling and simulation are understood as 'CIB&S methodologies'.

CIB itself is a scenario *method* (or technique),[117] meaning it has a *nomothetic* core that formulates rules, which structure a scenario construction process (see 3.1.1). On the other hand, all *design* related decisions concerning CIB are part of the *methodology*. This comprises the way CIB is concretely designed, e. g. if D&V are collected by desk research or expert interviews, if impact assessments are produced during stakeholder workshops or interviews, and what degree of inconsistency is chosen as being acceptable (see 3.2.2). All these decisions, necessary during each individual CIB analysis, are part of the *idiosyncratic scenario methodology,* comprising an individual interplay of methods, data and actors.

Methods comprise quantitative and qualitative forms of scenario methods, different types of models and their combined forms, as well as other methods of data and knowledge generation, collection, analysis, synthesis, integration and documentation; as well as all sorts of decision, facilitation, visualization, brainstorming, participation and other techniques. The methods chosen define the *technical design* of CIB&S methodologies, summarized in Table 7.

Actors of combined scenario methodologies using CIB are diverse and heterogeneous. Following Pulver/ VanDeveer (2009), I distinguish between *internal* actors that are directly included in the various phases of the construction process (also called "producer-user") and those *external* actors who are using scenarios (products) constructed by others ("recipient-user," ibid.).[118] Note that actors, who are internals with regard to one process step may be externals with regard to another. Overall, I roughly distinguish four central actor groups: *modelers,* who are responsible for the numerical mod-

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[117] In line with this study's use definition of 'method', see the differentiation between 'technical' and 'non-technical' by Grunwald (2013b: 16), i.e. the historical singularity (non-technical) vs. the reproducible (technical).

[118] Note that we are dealing with people and organizations doing and receiving the results of the research.

eling; *CIB scenario method experts* (in the following abbreviated as *scenario experts*),[119] who are responsible for the construction of CIB scenarios; *scenario groups* that are included in the construction of scenarios and comprise stakeholders, all sorts of experts or even laypeople (cf. van Notten et al. 2003), and *issue experts*, namely actors who provide selected information at selected moments. All of these actors have specific aims and interests,[120] and resources,[121] as well as structural—e. g. cultural, paradigmatic, disciplinary and organizational—backgrounds.[122] Their inclusion in different process steps, interactions, power and trust relations and more generally, inter- and transdiscipli-nary communication[123] describe the *social organization* of CIB&S methodologies, summarized in Table 7.

Table 7: Technical design, social organization and cognitive dimensions of CIB&S methodologies, operationalization and symbols used in this study

	Dimension	Operationalization	Symbol
Characterizing a CIB&S methodology	**Technical design**	What methods and techniques are applied? • CIB scenario process design, storyline writing technique • Modeling technique • Translation technique • Documentation format • Etc.	**method**
	Social organi-zation	Who does/ decides what? • Inclusion of different actors into different CIB&S activities • Responsibility, power, trust, support • Initiative and organization • Etc.	**actor**
	Cognitive dimension	What data is used, processed and produced? • Qualitative and quantitative data, information and systems knowledge • Assumptions, ideas, fears, hopes, expectations, assessments and beliefs on past, present and future developments • Etc.	**data**

On the social level, there is a potential for various designs of CIB&S processes—from the extreme of one person carrying out a CIB and a model analysis on her own, up to complex actor constellations

119 Note that other actors, beyond those with expertise in CIB, might be or might consider themselves to be scenario experts, too. Also, modelers might be the ones with CIB method expertise themselves. In the following study, the term scenario expert refers to those that are CIB scenario method experts.

120 With regard to incentives for inter- and transdisciplinary cooperation see e. g. Wätzhold et al. (2009), who argue that especially (qualitatively oriented) social scientists have little incentive to engage in transdisciplinary environmental research due to the lack of opportunities to publish, an expectation from the hard sciences that they will provide a service (social scientists as service provider only) and the fact that (future oriented) research questions have less relevance in their communities.

121 E. g. time, money, abilities, but also decision-making power.

122 This kind of activity is also embedded in institutional structures, e. g. in the form of research and funding landscapes, and finally the science and research system.

123 For the specifics of inter- and transdisciplinary cooperation, see e. g. Wätzhold et al. 2009, Berger 2000, Bergmann et al. 2010, particularly with regard to communication and “common language” Janich and Zakharova (2014).

including different actors during different activities reflecting specific initiatives, the organization of responsibilities, the distribution and dynamics of power and trust, and requiring specific levels of support. The literature indicates that an important feature of the social organization of combined scenario processes is, whether or not actors from the scenario and modeling groups participate during their respective activities.

Data, as in the framework by Hinkel, are understood in a wide sense, comprising data, information, knowledge (also in tacit, local or scientific or other forms) with a special focus on assumptions, ideas, expectations, hopes and fears, as well as assessments of and beliefs on past, present and future developments. The data used, processed and produced within CIB&S methodologies characterize the *cognitive* (or data related) *dimension* of these methodologies.

This basic framework is used to analytically divide CIB&S methodologies into their elements, to allow their comparison and to make visible as well the effects of factors beyond CIB and beyond numerical modelling. In section 4.4, I return to this framework and attempt to extend it from the mere description of methodologies to a basis for searching for the effects of one method (CIB) within a combined scenario methodology (CIB&S). In the following section, further conceptual elements are introduced to specify the different *activities* of CIB&S processes and to characterize *forms* of the combination of CIB with numerical modeling.

4.2 Process scheme and forms of CIB&S

In this section, I present concepts of CIB&S processes that I have derived from the literature review on combined scenario processes: A process scheme defines central phases and activities of CIB&S methodologies and the various resulting scenario products (4.2.1). Furthermore, I propose three central dimensions to characterize different forms of the combination of CIB with numerical modeling (4.2.2). These concepts are developed to describe, analyze and compare different real-world processes.

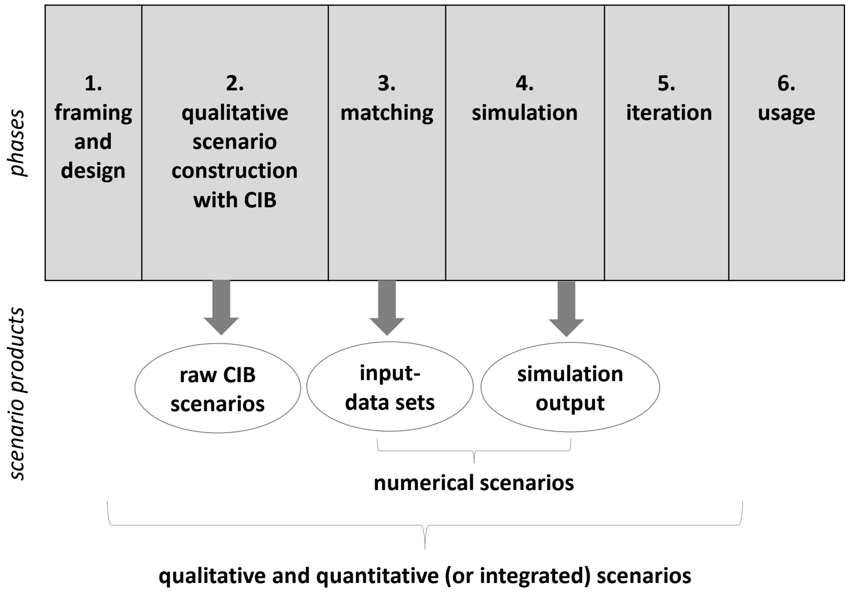
4.2.1 CIB&S scenario process and its scenario products

In this section, I propose a process model or scheme of CIB&S processes. This scheme is derived from the literature on SAS-type approaches and integrates the (assumed) specificities resulting from the use of CIB *instead* of IL.

The literature provides some proposals for structuring SAS-type scenario processes into specific phases. Based on these, one can sketch a process scheme consisting of six phases: 1) framing, 2) construction of the qualitative scenarios, 3) matching, 4) simulation, 5) iteration, and 6) usage. I assume that using CIB within such combined scenario processes has direct—that is first- order effects—mainly on phase 2, the construction of the qualitative scenarios: More intuitive approaches to qualitative scenarios are either added or substituted by the use of CIB to construct qualitative scenarios. Figure 6 shows such a process using CIB instead of IL in the form of a (simplified) linear process model including typical scenario products. The phases are further specified in the following.

Figure 6: CIB&S process scheme: simplified linear process model and its resulting scenario products

My illustration, based on comparable proposals by Döll/ Krol 2002, Döll 2003/2004, Alcamo 2008, Erdmann/ Hilty 2010, adapted to CIB&S processes.



4.2.1.1 Framing

During phase 1, *framing,* the objectives, the thematic scope, and the temporal and geographical scale of the scenario construction process are decided upon. The design of the process is adapted accordingly, covering decisions about (scenario) methods, techniques and (numerical) models to use as well as the organization of processes and products and of the inclusion of actors at different steps in the process.

4.2.1.2 Qualitative scenario construction with CIB

Phase 2, *qualitative scenario construction,* can be further divided into three sub-steps, in case CIB is used (see also chapter 3).

2a) *Selection and definition of (D&V).*

2b) *Cross-impact assessment.*

2c) *Analysis of the matrix using the CIB balance algorithm* to search for internally consistent configurations, i.e. internally consistent scenarios, and selection of a CIB scenario sample.

All possible solutions of the cross-impact network are called *raw CIB scenarios*. Note that the raw CIB scenarios comprise the different (semi-)automatic presentation formats provided by the CIB scenario software (e. g. in table form or in the form of protocol outputs including impact diagrams). CIB does not automatically produce narratives or storylines. *Storylines* are defined as additional textual descriptions of the solutions of the impact network. They might use the information on interrelations between descriptor states that are stored in the CIB matrix, but often include additional qualitative detail, going beyond the raw CIB scenarios.

4.2.1.3 Matching

In phase 3, *matching*, qualitative scenario construction is linked with numerical modeling. I propose to distinguish between two levels, the level of scenarios (level I) and the level of underlying models (level II). 'Matching on level I' comprises the *translation* of qualitative scenario information into numerical input that is digestible by the mathematical (simulation) model. On this level, matching refers to the level of input data and model restrictions.[124] 'Matching on level II' refers to further reciprocal comparison and adaptations of internal structures of both the CIB model and the numerical model. On level II, matching refers to model boundaries, elements, internal and external relations, see Table 8.

Table 8: Correspondences between a conceptual CIB model and a numerical simulation model as two types of system models

System model	**Conceptual CIB model**	**Numerical simulation model**
Elements	List of descriptors	System elements, inputs, outputs
Future developments	List of variants	Development of system elements, inputs, outputs over time
Interrelations	Semi-qualitative impact assessments	Mathematical equations/algorithms defining interrelations between (system) elements
System state / system development over time	Network configurations, i.e. scenarios (rather static)	Alternative future system states (static) developments of system over time (dynamic) - Sets of input data (firstst half of num. sc.) - Model output (second half of num. sc.)

Matching on level I, the translation of qualitative CIB scenarios into numerical input for the simulation model, can be (analytically) separated into further sub-activities:

3a: *Specification, i.*e. defining numerical indicators (for model inputs) and model parameters (e. g. restrictions etc.), representing the qualitatively expressed scenario ideas.

3b: *Quantification, i.e*. defining numerical values for the indicator, e. g. in the form of time series, which requires to define a base year, base year values and assumption on the character of future numerical development, as for example linearity or others.[125]

3c: *Bundling,* i.e. the combination of individual input data into sets, which represent the raw scenarios.

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[124] Note that in modeling communities, the distinction between what is a model input and what a parameter is often defined by convention only.

[125] Note that the definition of indicators and of numerical values can occur after the CIB as suggested in this scheme or already during the CIB analysis in phase 2, e. g. in parallel with the definition of D&V.

On the level of scenario products, matching results in the first half of the numerical scenarios, namely the input data sets.

I assume that CIB has effects on matching due to its systematic character. The use of CIB (instead of IL) does not automatically make a difference with regard to matching on level I, as CIB does not provide automatic answers to the difficult tasks of specification and especially quantification of qualitative statements. But CIB, like any other systematic scenario technique, has the potential to be more explicit when it comes to the bundling. However, I suppose that the use of CIB might make a more specific difference with regard to matching on level II, because through the character of CIB as a conceptual model, the comparison not only of assumptions on future development but also of their interrelations (accessible in the matrix) could be supported. Matching on level II could result in reciprocally adapted conceptual and numerical models that underlie the scenarios.

4.2.1.4 Simulation

During phase 4, s*imulation*, a mathematical model carries out simulation runs using the input data sets defined in phase 3, that is the first half of numerical scenarios, and calculates model outputs, that is the second half of the numerical scenarios.

4.2.1.5 Iteration

In phase 5*, iteration* occurs—that is to say the numerical scenarios, simulation input and output, are interpreted, compared with the qualitative scenarios, and used to refine and re-define the first half of the numerical scenarios (feedback to matching) and/or the qualitative and/or raw CIB scenarios. Iterative activities are described by Alcamo on several levels.[126] Thus, the term iteration is not used in its strict mathematical sense. Instead, it is used to describe activities comprising the interpretation of results, the comparison with other components, and adaptations to obtain, so to speak, a better fit between components. As a consequence, an iterative scenario process is not linear but includes feedback loops and requires that the process remains to a certain degree open to refine the results by going back and forth between the components. The products are not finalized in the first round but are refined by further rounds of review.

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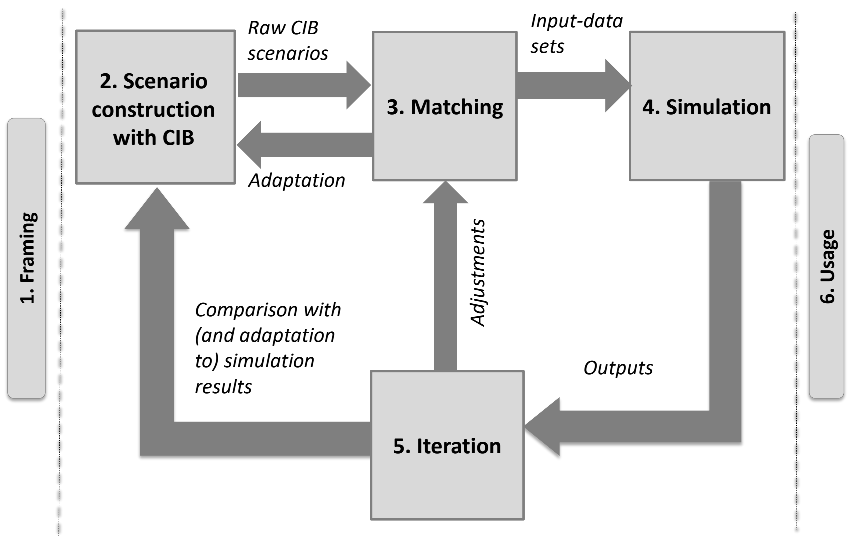
[126] *Iteration a): The simulation results are brought together with the storylines:* As in Alcamo (2008: 137 ff.), the storylines are refined based on the model results. On the one hand, they are compared with the models "to identify inconsistencies" (ibid: 139) and on the other hand, they are enriched with quantitative model results. Then a second version of the storylines is drafted.
Iteration b): Refine the quantification and the simulation and thus the qualitative and quantitative formulations of the scenarios (internal): The quantification, the simulation and the refinement of the storylines (Steps 4 to 6 in Alcamo's SAS) are iterated two or three times until the scenario panel and team consider the qualitative and the quantitative scenarios to be "complete and sound" (cf. Alcamo 2008: 140) (step 7).
Iteration c): Refine qualitative and quantitative scenarios through external revie: Then the process is opened up to external agents (cf. Alcamo 2008: 140, step 8 and 9), the scenarios are broadly distributed for multiple feedback and reviews (step 8), storylines and model runs are revised (step 9), and the final versions of storylines and quantified scenarios are produced.

This non-linearity is also supposed for CIB&S processes. Figure 7 shows the main phases of an ideal CIB&S process, including the links (and feedback) *between* the different phases (omitting additional feedback that might occur *within* the individual phases):

Figure 7: Non-linear CIB&S process model



To carry out a *full iteration*, in the sense of SAS, within a CIB&S process would mean not only to adjust the numerical inputs in function of simulation results, but also to revise the CIB matrix and thus, very probably also the resulting scenario sample.

Phase 5 results in further scenario *products*, namely fitted raw CIB scenarios and numerical scenarios, potentially also further developed into storylines, and/ or some sort of integrated scenario presentation. Table 9 sums up the *scenario products* resulting from such a CIB&S process*.*

Table 9: Scenario products resulting from a CIB&S scenario process

Raw CIB scenarios	Results of a CIB analysis, i.e. the list of constellations of a CIB impact network (as presented e. g. by a CIB scenario table).
Narrative scenarios/ storylines	More elaborate literary descriptions (and possibly also visualizations) of these raw scenarios, using the information on interrelations between descriptor states that are stored in the CIB matrix.
Numerical scenarios	Comprising the numerical input data (first half) and simulation results, i.e. outputs (second half).
Integrated scenarios	Joint and interwoven representations of qualitative and quantitative scenarios.

4.2.1.6 Usage

In phase 6, *usage,* the resulting raw CIB scenarios (and/ or storylines) and numerical scenarios *or* integrated forms are further processed by internal and/or external users to serve further scientific exploration and/or policy advice.

4.2.2 Forms of the combination

The review of the literature concerning combined scenario processes showed that a large variety of designs of methodologies was implemented already. The different forms in which storylines and simulations are combined can be characterized by several dimensions (cf. 2.3.2). I propose to use three groups of dimensions to characterize forms of CIB&S methodologies namely the *system representations* of the CIB and of the model(s) (4.2.2.1), the relative *positions* of both components within the process (4.2.2.2) and the *link* between the two components (4.2.2.3). The three dimensions and their definitions are summarized in Table 10.

Table 10: Dimensions to characterize forms of CIB&S methodologies, operationalizations used in this study.

	Dimension	Operationalization
Characterizing the CIB and the model(s), and their relation.	**System representation of each component**	What do the different system representations look like? • Division of labor between CIB and the model(s) • Scope (what is inside, what is outside; what is endogenous, what is exogenous?) and granularity • Overlap of the two system representations • Qualitative and/or quantitative representation?
	Position of both components	What role do both components play with regard to each other and in the overall process? • Timing: What comes first? (Model(s) pre-existing or newly developed?) • Dominance/ structuring the process • Benchmark for adaptations
	Link between the components	How are both components linked to each other? • Type and degree of coupling • Forms of iteration

4.2.2.1 System representations

The first dimension to characterize forms of CIB&S is the system representation by each of the two components, that is, by the conceptual CIB model with its resulting raw CIB scenarios and by the numerical simulation model with the numerical scenarios.

The literature review has shown that in combined scenario applications, there is often a specific *division of labor* defining what is expected to be represented and dealt with by each component (cf. the somewhat stylized Table 2 in 2.3.3).[127] In combined scenario approaches using CIB, the expected functions of CIB might be similar to those expected from exploratory qualitative storylines, namely above all to represent the qualitative, socio-economic (contexts or) drivers and/or policy regimes.

[127] The reciprocal expectations might be conflicting or even contradictory among the members of one project. Conflict may arise e. g. if the social scientists involved draw the line of division between social and natural sciences, whereas the natural scientists might split so-called scientific facts from so-called uncertain, subjective and messy stuff. Another source of conflicting understanding could arise, if social sciences and qualitative knowledge is set equal, and furthermore set equal without differentiation with non-scientific knowledge namely laypeople's and community knowledge.

Further aspects of this dimension are the issues of *scope* and *granularity* of the two system components. They refer to the definition of what is included in each of the system representations and what is not, and what aspects are considered exogenous and endogenous. Furthermore, this dimension deals with the degree of *overlap* of the two system representations (with regard to system boundaries, elements and interrelations, cf. also Table 8 above). Do both cover the same sample of the real world through different approaches or do models and qualitative scenarios cover complementary parts? How do the representations differ or match in their (geographic or thematic) scope and granularity? To what degree do the representations overlap with regard to their respective system borders, the elements and the interrelations they represent and the ones they do not represent? Possible variants are the following ones.

a) *Separated systems* (practically) without overlap, e. g. CIB representing social (context) systems, the numerical model (s) environmental system(s), each one with its specific scope and granularity.[128]

b) CIB and the numerical model both represent the *same* (e. g. socio-environmeental) *system*, but with different granularity (e. g. with the CIB including only a simplified version of the functional logic of the numerical model, and the numerical model including all quantifiable parts of the CIB system representation, in the form of input assumptions and in form on assumptions on interrelations.[129]

c) *Mixed types* with partially overlapping representations with diverging scopes and levels of granularity.[130]

The definition of the patterns and degree of overlap (static results) are in relation to the issue of coupling between both components (see below).

4.2.2.2 Position

The second dimension to characterize forms of CIB&S is the relative position of both components within the process. The role both components play with regard to each other and within the overall process, first of all seems to depend upon their *timing*. The position is linked to the question, what comes first? What exists or is established first (cf. chapter 2, scenarios first vs. models first)? Still, the *dominance* of the process by one of the components might depend not only from the timing, but also from the question of which one of the two gets more attention, time or resources, and finally, which

128 The minimal overlap in this version is that the social system represented by the CIB is the relevant (social) context for the model and relevant to understanding and interpreting the model results—otherwise there would not be one combined approach but two separate ones.

129 This idea is also expressed by Kemp-Benedict (2004: 4).

130 One could distinguish those variants in which the CIB provides relevant context information to the model in the form of input data from those in which the CIB represents (some) of the model’s inner logic in a simplified way, too (i.e. overlap with regard to inner or outer model parts).

one is the *benchmark* in cases of reciprocal adaptations and adjustments. Which one steers and which one adapts? (cf. chapter 2 scenarios lead, models lead and equal cooperation). The position of the components presumably is closely linked to the weight and dominance of people in the process and to their preferences, too.

4.2.2.3 Link

The third dimension to characterize forms of CIB&S is the *link* between the components. The link between CIB and numerical models comprises the issues of coupling and iteration. I would like to distinguish four characteristics of links:

1) The *type* of link, 'soft' (or indirect) link vs. 'hard' (direct) link (with reference to Winterscheid 2008: 130). Soft links describe all activities involved in relating one component or type of scenario verbally with the other. This includes the joint interpretation of results (as for example of raw CIB scenarios and numerical scenario results) and all other sorts of linguistic and argumentative relations.[131] Hard links describe all activities involved in importing parts of one component into the other (e. g. 'output-input coupling' of models, with reference to Conrad 2010: 9 ff.). This type of link may include the task of translating qualitative CIB scenarios into numerical input data sets, or, the other way around, of numbers into verbal statements or model equations into semi-formalized impact assessments.
2) The *level* of link, namely on the level of scenarios only or on the level of the underlying models and their internal structures (cf. 4.2.1 matching).
3) The *direction* of the link, distinguishing between unidirectional and bi-directional ones, i.e. from the CIB to the model (or from the model to the CIB) and back (i.e. with feedback).
4) The *explicitness* of the link, discerning between explicit and implicit links.

In SAS, as described by Alcamo (2008), the link between storylines and models is both soft, namely through the joint interpretation of results, and hard, namely through the output-input link from storyline-based input data sets into models. It is bi-directional, since storylines inform the input of model runs and model results inform storylines. The link is iterative, meaning not produced only ones, but both components and the different types of scenarios are refined through repeated iterative loops through the process (cf. also 4.2.1, iteration). In sum, the type of link influences the degree of integration of both components.

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131 Note that the purely qualitative CIB scenario factors are indirectly (or softly) coupled to the numerical models too, because through the CIB-matrix they are linked to those factors that are translated and coupled directly/in a 'hard way' to the model (cf. also Weimer-Jehle et al., forthcoming).

4.3 Defining scenario traceability and scenario consistency

In the foregoing literature review (chapter 2), I argued that traceability and consistency pose central unsolved challenges to combined scenario approaches of the SAS type. To explore effects of CIB with regard to traceability and consistency, both concepts need to be operationalized. As also shown above, current scenario literature does not agree with enough precision on the definition of these concepts.[132] Therefore, in the following, I propose new working definitions that are used within this study to operationalize scenario traceability (4.3.1) and scenario consistency (4.3.2).[133]

4.3.1 Scenario traceability

Based on a transdisciplinary and common-sense-based understanding, a process is traceable, meaning one can *follow* what was done and how a process came to its results. [134] Traceability on the one hand refers to what is called Nachverfolgbarkeit in German. *Nachverfolgen* means to trace or to track something. It rather neutrally describes the possibility of tracing a result back to the underlying processes. On the other hand, traceability also resonates with what is called Nachvollziehbarkeit in German. *Nachvollziehen* means to understand, to comprehend something. It describes cognitive and rather subjective processes of opening up to the reasons behind something. One might trace something without understanding it. The latter is more demanding, as it not only requires insight into activities, decisions and selections that are made during a process, but also insight into and openness for the reasons underlying these. Still, traceable does not mean agreeable: One does not need to positively assess either a process nor a result—nor the reasons and justifications that have led to these, and one might have diverging reasons to perform a process very differently.

Scenario traceability more specifically refers to the *process* of scenario construction, namely to the ingredients that are used and the process of relating them to each other (Grunwald 2011) as well as to further processing and presenting them. The ingredients comprise, following Grunwald (2011), heterogeneous elements of knowledge, but also of expectations, fears and hopes. These can be summarized rather generally under the term of assumptions on future developments or 'scenario assumptions'. The term assumptions explicitly refers to the understanding that these are present

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132 One could also have chosen to consider literature more broadly, considering transdisciplinary research in general, including conceptualization from model-related domains such as mathematics, or by asking scholars from fields such as cognitive or communication research and philosophy for their theoretical approaches to traceability and consistency. This was not feasible within the scope of this study but is strongly suggested for further research.

133 Both working definitions are based on what I have learned from the review of the scenario literature as well as on the expected performance of CIB, as these are the issues I need to 'measure' in the following empirical part of the study.

134 This understanding of traceability is also close to the meaning of 'traceability' in process informatics or in the context of food supply chains, where it is also linked to accountability issues, meaning who (or what) has caused what outcome.

statements (as in Grunwald 2011), or present statements on scenario uncertainty (as in Walker et al. 2003). I distinguish two types of scenario assumptions, namely assumptions on future developments and assumptions on the systemic characteristics that link them.

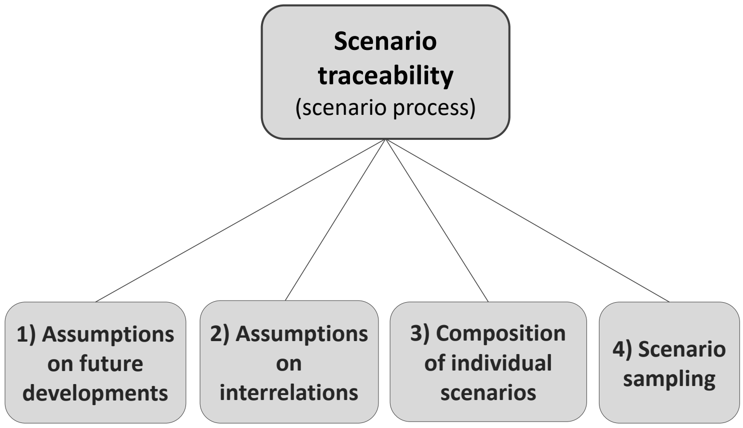
The relating, processing and presenting of the ingredients then refers to the procedures of scenario construction, often structured by specific scenario methods providing specific rules for doing so. This comprises two central dimensions: On the one hand the composition of individual scenarios, that is the combination of individual scenario assumptions into an overall bundle; on the other hand, the definition and selection of a scenario sample, that is the selection of distinct alternative scenarios for the same scenario field and future space.

Scenario traceability is understood as a *subjective category* depending on the access to information about ingredients and their mixing (e. g. by internals vs. externals). In addition, perceived traceability might also be influenced by the scenario user's expertise in the method and background knowledge, as well as the effort (s)he invests in tracing the process of constructing a scenario. Especially in combined scenario processes, scenario traceability is assumed to be an issue for internal users as well as external ones: In integrated scenario processes, scenario groups, modelers and scenario experts, depending on the design of actor inclusion, might be internals to some of the scenario construction activities—but external to others. Therefore, this definition distinguishes between i*nternal* scenario traceability, that is to say traceability for internal actors of the entire process,[135] and *external* scenario traceability, that is to say traceability for completely external actors—actors that have not participated in any of the scenario construction activities.[136] Furthermore, it distinguishes between the perceptions of users that are (method) *experts* (e. g. modeling experts, scenario experts) and *laypeople*[137] with regard to the methods used. In this sense, an internal qualitative scenario expert might be a layperson with regard to the numerical model, e. g.

Overall, tracing scenario construction means that an (internal or external, expert or lay) user of the scenarios can trace the following four dimensions, see Figure 8.

[135] Which might be a precondition of internal scenario legitimacy.
[136] Which in parallel might be a precondition for external scenario legitimacy.
[137] Schütz (1972) further distinguishes between the man on the street and the well-informed citizen.

Figure 8: Dimensions of scenario traceability (working definition)



1) *Assumptions on future developments*: What alternatives have been included as possible and relevant future developments?[138]

2) *Assumptions on interrelations between future developments*: What logic or overall system representation lies behind the scenarios, i.e. what was assumed on interrelations between future developments?

3) *Individual scenario composition:* How have individual scenarios been composed? How was their composition decided upon and why do they look the way they look—and why do they not look different?

4) *Scenario sampling*: Why has this scenario sample been chosen and why not a smaller, bigger or different one, focusing on other scenario features (e. g. extreme scenarios). In sum, why have these n= x scenarios and not, e. g., n= y + 2 scenarios been chosen?

Note that traceable assumptions on future developments can be considered a precondition for traceable assumptions on interrelations; and that a traceable composition of individual scenarios seems to be a precondition for a traceable scenario sample.

4.3.2 Scenario consistency

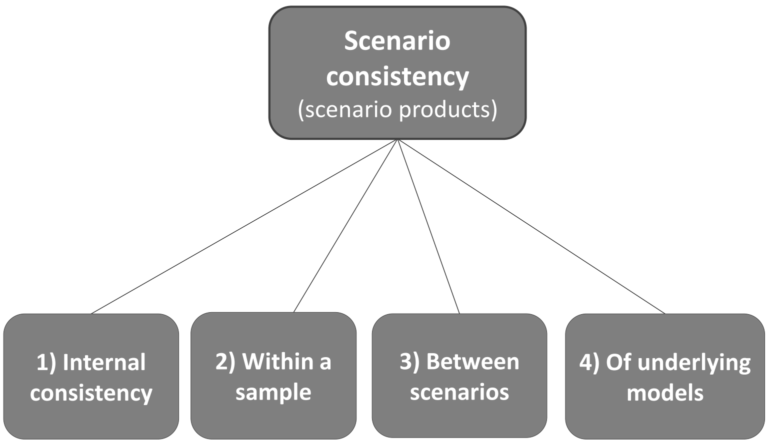
Based on a transdisciplinary understanding, consistency means that something makes sense and is coherent in itself. This understanding fits the general definition that something is consistent, if it does not show inconsistencies and does not contain contradictions.

[138] One a deeper level, one does not only access these assumptions, but one also has access to the *reasons* for these assumptions (that is, one goes from tracing to understanding). And these reasons again are based on assumptions. As assumptions more generally are a matter of infinite regress, I chose to start with the most superficial level of tracing—and to keep in mind that there are always underlying, deeper levels.

First*, scenario* consistency more specifically refers to scenarios as *products* as scenarios texts, films, tables and graphics. A scenario product can be assessed as consistent or not—not the scenario process leading to it. Nevertheless, it is the process of constructing the scenario that contains the reasons for (in-)consistencies. Second, scenario consistency is understood as a *relational category*, meaning something is (in-)consistent with something else: (A) and (B) are (in)consistent; with A and B both being scenarios, scenario elements, or underlying (numerical, conceptual, mental etc.) models. Third, scenario consistency depends on the *consistency criterion* applied, meaning A and B are (in) consistent with respect to a specific *definition* of consistency (x). With regard to scenario consistency, these criteria can be either intuitive (holistic) or systematic (formal) consistency concepts: On the one hand, a scenario can intuitively match one's ideas and its intuitive consistency can be judged by subjective assessment. On the other hand, a systematic-analytic consistency concept follows formal rules that make it possible to more objectively decompose and recompose its logic; examples for systematic- analytic consistency criteria are causality and coherence. I assume that different consistency criteria can create conflict. A scenario pair that is consistent accorging to the CA is not necessarily consistent according to CIB—and it is an open question whether a scenario pair consistent with regard to a formal criterion is also intuitively *perceived* as a consistent one by (internal or external) users. In sum: *(A) and (B) are (in-)consistent under criterion (x)*; with A and B being scenario (elements) or numerical, conceptual or mental models.

In this study, I propose to distinguish between four levels of consistency shown in Figure 9:[139]

Figure 9: Levels of scenario consistency (working definition)



[139] These four levels of consistency correspond to those levels one can distill from texts on SAS-type approaches.

1) *Internal consistency* refers to the question of whether an individual scenario is consistent with itself. Or, to turn it into a relational formulation, whether the assumed development of each scenario element is consistent with the assumed developments of all other scenario elements.

2) *Consistency within a scenario sample* (or scenario set) refers to the question of whether all scenarios of one sample are consistent with one another.[140]

3) *Consistency between different forms of one scenario*, e. g. between a narrative and a numerical form of a scenario, refers to the translation of scenarios into different forms in integrated scenario approaches. In other words, the question at this level of consistency is: Are the numerical scenarios consistent with their corresponding narrative scenarios? With regard to consistency between a *numerical scenario* and *qualitative scenarios*, we propose to distinguished two steps:

   a) Is the first half of numerical scenarios, i.e. the quantitative input data sets, consistent with the corresponding sample of qualitative storylines?

   b) If yes, are the second half of numerical scenarios, i.e. the model calculated indicators (output) also consistent with the corresponding qualitative storylines?

4) *Consistency of underlying models* refers to the system representations underlying the different (numerical, narrative etc.) forms of a scenario sample, comprising system boundaries, system elements, internal and external relations. The question is, whether the (qualitative) system representation underlying one (narrative) scenario is consistent with the (numerical) system representation underlying the corresponding (numerical) scenario? In principle, this level of consistency refers to all different types of models thinkable, that is, *mental* models of different actors or actor groups as well as *conceptual* and *numerical* models that can be compared within one group or with each other.[141]

Consistency on one level can but does not need to relate to consistency on other levels. On each level, different consistency criteria can be applied. Note that on all four levels, scenario builders may have very good reasons *not* to strive for consistency but instead, to explicitly focus on—or to live with—inconsistencies.

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140 This level refers to two aspects: 1) to the scope, scale and granularity of different scenarios of one sample, that is by asking, whether all scenarios of one sample represent alternatives of one and the same future space (cf. also Stauffacher/ Muggli/ Moser, forthcoming); 2) to assumptions on interrelations, that is by asking if assumptions on interrelations between scenario elements made in different alternative scenarios are consistent. In other words, do scenarios assume the same (linear or disruptive) development and the same promting or hindering interrelation between two scenario elements?

141 To be compared with regard to their consistency, these system representations need to be accessible. That points to the links between scenario traceability and consistency.

Two aspects related to consistency have been excluded from this study. First of all, taking the warning of van Asselt et al. (2010) seriously, I explicitly exclude ‘consistency with current knowledge’ from this working definition of scenario consistency. This is done in order *not* to fall into the trap of historic determinism but rather to consider scenarios from the futures uncertainty repertoire and thus in their condition as artefacts only.[142] Second, for reasons of feasibility, no systematic study of *mental* models is carried out in this study.[143]

To refine the new working definitions of scenario consistency and scenario traceability and to (pre)test their practicability, I have applied them to classical (ideal type) scenario approaches. Annex F summarizes the (plausible and idealized) effects of these different scenario approaches on scenario traceability and scenario consistency as understood in this study. This pretest also helped in the effort to prepare more concrete expectations of the effects of the use of CIB within combined scenario methodologies. Before presenting the *expectations* of this study in detail (4.5.), I first need to turn to the question of how to empirically isolate effects from the use of CIB within combined scenario methodologies, that is from the multiple and mingled effects of other elements in these methodologies.

142 With Grunwald (2011), I argue that scenarios are always made of different elements, only one of them being knowledge about the past and the present, others being assumptions on future developments and normative elements like hopes and fears. Thus, it is certainly possible to check, whether the knowledge components of a scenario are in accordance with the state of research. In opposition, the assumptions and the normative components cannot be judged by whether they are ‘right or wrong, true or false, they can only be plausible and consistent or not, transparent or untransparent etc. Different scenarios (i.e. different sources of current ‘future knowledge’) can thus be consistent or inconsistent with each other for different reasons. And only one reason is that they do not agree on the current knowledge—but rather because they vary in framing and perspective, in assumptions about plausible future developments, and/or in the normative position towards these developments.

143 This study is not a socio-psychological or cognitive science study and therefore cannot *systematically focus* on the consistency of scenarios with the *mental* models of the participating actors. Still, the influence and relevance of these mental models is acknowledged and evidence is considered, albeit not collected systematically, as this would have gone beyond the scope of this dissertation project. I assume that the mental models of the system under representation of the different actors participating in a CIB&S process (actors in the scenario group, the scenario experts, the modelers, external experts etc.) are not identical but might, especially at the beginning of the process, contain diverging ideas on the system under study. Do these mental models change during the process? And to the mental models of the scenario group, the scenario experts and of the modelers at the end of the process) match with the conceptual CIB model? I.e. do the different participant actors ‘identify’ with the CIB model? How strongly do actors need to be involved to achieve this identification/influence on the process? If there is dissent concerning the mental models, how is this dealt with? (Within the scenario-group or between scenario-group and modelers?) How much is a consensual group model a compromise—and is ownership given, nevertheless? What is the scenario experts expert’s influence on the CIB model when it comes to content? How do actors experience mismatches with their mental models? This issue refers also to the question of whether or not the subjective assessment of consistency of scenarios by actors matches with the systematic consistency criterion of CIB. Overall, this avenue points several open questions that need to be dealt with by future research.

4.4 Identifying effects of a single method within combined scenario methodologies

How is it possible to identify effects of a single method within the complexity of combined scenario processes? In this section I clarify, how I attempt to trace the effects of CIB—when it is used within complex combined scenario methodologies, in which many further methodological elements, conditions and their interplay (in idiosyncratic constellations) are assumed to have effects, too. First, I make the basic assumptions of this study on (the limits of) the effects of scenario methods explicit (4.4.1). Second, I characterize different types of possible effects (4.4.2) and finally, I present the approach of this study that consists in describing scenario methodologies, assessing their outcomes and interpreting possible connections between both, methodologies and outcomes (4.4.3).

4.4.1 Basic assumptions

Generally, this study is based on the assumption that, so to say, scenario methods matter:

A1: Scenario methods have an effect on scenario processes and products, as scenario methods structure scenario processes and the resulting products.

Note that the opposing assumption would be that the scenario method used does not make any difference, meaning that the method has no effect. Second, this study assumes that scenario methods do not matter alone, but are adapted to individual project settings and interact with other elements of a scenario methodology.

A2: Scenario methods are not the only elements with effects on scenario processes and products; other elements of individual methodologies and their conditions matter, too. Scenario methods do not structure (interdisciplinary) scenario processes alone; rather their individual application has an effect together with other methods and techniques, actors, and data and individual conditions in idiosyncratic configurations (methodologies) (see Table 7).

Transferring these assumptions to the use of CIB within combined scenario methodologies, I assume that the use of CIB within combined scenario methodologies has an effect on the combined scenario processes and on their outcomes, but that these effects are generated not only by CIB but, in addition and for each individual case individually:

a) They are influenced by the design of the application of CIB.
b) They interact with effects of further elements of combined scenario methodologies, that is the interplay with other methods, actors, data and conditions.

Thus, I expect the CIB method to support the combined scenario methodology aimed at the construction of socio-environmental scenarios, but not to generate automatic or deterministic effects.

4.4.2 Types of effects

I propose to distinguish several *types* of possible effects of CIB. The concepts are borrowed from the field of Technology Assessment (TA), where they are used to characterize the effects of the use of techniques and technology (cf. Grunwald 2010, Decker 2013). I have argued that a scenario method can be considered a technique (in the sense of Grunwald 2013b). In consequence, looking for effects of CIB within combined scenario methodologies can be considered as being some form of meth-od(ology) assessment—in analogy with technology assessment (TA).

4.4.2.1 Intended effects vs. unintended effects

First of all, one can distinguish between the *intended* effects, meaning those corresponding to the intentions, goals, and aims associated with the use of a technique (cf. Decker 2013)[144] and those that were not intended (*unintended* effects). Intended effects are often (but not necessarily) equaled with *positive* effects or *main* effects and are generally associated with a striving for progress (cf. Grunwald 2010: 20). The unintended effects are often (but not necessarily) associated with *negative*, or *side*-effects. This classification of effects is a subjective one, depending on an actor's intentions, assess-ments and anticipated benefits.

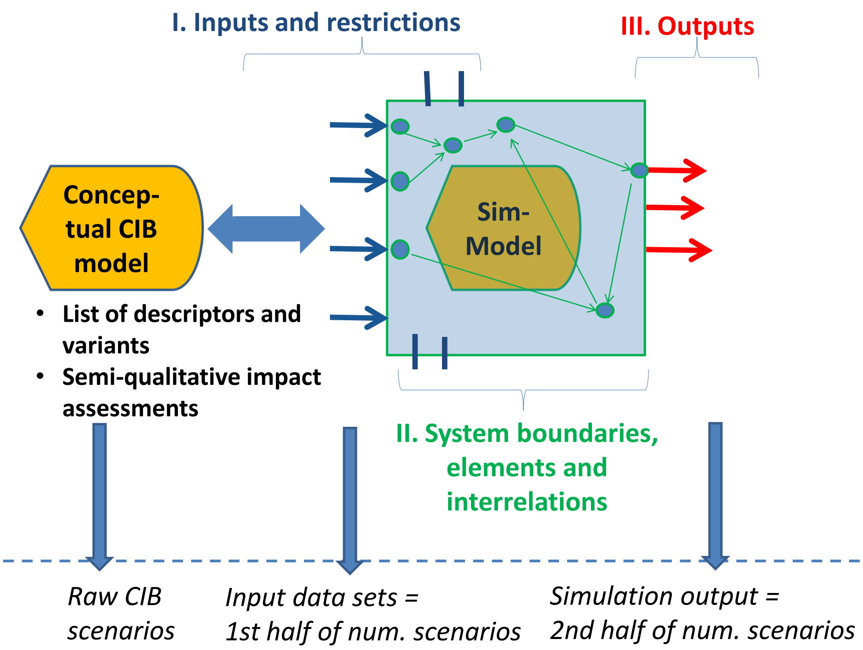
The central intended effects of the use of CIB within combined scenario methodologies under study here are to enhance scenario traceability and consistency.[145] This study aims to remain open to the unintended effects of the use of CIB in combined scenario methodologies, too. To gain some distance from the normative connotation of these labels (cf. foregoing paragraph), in the following I use the term 'other effects'.

4.4.2.2 First, second and third order effects

I propose to distinguish between *first* or primary (direct) and *second order* or secondary (indirect) effects of the use of CIB on scenario construction.[146] CIB has *first order* effects on the construction of (qualitative) raw CIB scenarios (e. g. through the use of the CIB balance algorithm). Within combined methodologies; CIB might have further second order effects, e. g. on the construction of the *numeri-cal* scenarios, too. Figure 10 shows the potential second order effects of the use of CIB on the numer-ical side of combined methodologies (on numerical modeling and simulation and the resulting numerical scenarios).

[144] Decker specifies that these are the explicit effects.
[145] The literature review documented in chapter 3 has shown that other effects could have been focused too, such as knowledge integration, see e. g. Prehofer and colleagues (forthcoming).
[146] See e. g. Decker (2013: 34).

Figure 10: Possible second and third order effects of CIB on numerical scenarios, analytical split of effects on three levels



These second order effects of CIB can occur at three levels: First, secondary effects can occur on the definition of numerical model input and restrictions, i.e. on the first half of the numerical scenarios (through matching on level I, when raw CIB scenarios are translated into model input (level I in Figure 10). Second, secondary effects occur, when model structures (boundaries, system elements, interrelations) of the conceptual CIB and the numerical model are compared or even adapted to each other (matching on level II). Third, both second order effects (I and II) sum up to *third order* effects of CIB on simulation output, i.e. on the second half of the numerical scenarios (level III).[147] Note that considered from a different perspective, and especially on level II, the numerical simulation model and the numerical scenarios might have effects on the CIB, too (indicated by the double pointed arrow in Figure 10).

Finally, effects playing out at one moment of a process can induce other effects, sometimes automatically, in the later course of the process. With regard to CIB, the question is whether or not CIB effects are propagated throughout combined scenario methodologies, and if yes, how.

4.4.2.3 Individual vs. systemic effects

Furthermore, I would like to distinguish between *individual* effects on the one hand (those that can be easily isolated) and mingled or *systemic* effects on the other hand (those resulting from several interrelated influences) (cf. Decker 2013: 34). The individual effects of CIB need to be distinguished from the systemic (and potentially *emergent*) effects of complex combined scenario methodologies

147 The non-quantified parts of the qualitative CIB scenarios also have indirect impacts on numerical scenarios as they are, through the CIB-matrix, linked to those factors, which are directly coupled with the model (cf. Weimer-Jehle et al. forthcoming).

in total. The more *complex* the causal situation, and the *longer* the causal chain (cf. also higher order effects), the less hard the proof of effects of CIB can be; because other elements and/or events need to be suspected of being the causing elements, too (cf. also Decker 2013: 34).

4.4.2.4 Necessary vs. contingent effects

Finally, I distinguish between *necessary* and *contingent* effects (cf. Decker 2013: 35 ff.). Necessary effects are those that result (in quasi-deterministic manner) from the application of a technique (in this case from the adequate application of—the method's core of—CIB). Contingent effects do not occur automatically, but are uncertain due to their future openness: whether and how they occur depends on the situation, contexts and conditions and the complex interplay of causing elements.

4.4.3 Analyzing methodologies, assessing outcomes, interpreting effects

In this section, I sum up how this study attempts to trace the effects of the use of CIB within complex combined scenario methodologies. In the preceding sections I have assumed that CIB has effects on combined scenario processes and products, but that these effects are embedded in complex and idiosyncratic constellations, also called scenario methodologies. Within these, many further methodological elements, conditions and their interplay are relevant, too.

With regard to the identification of effects, I have stated above (with reference to Decker 2013) that the more complex the causal situation, and the longer the causal chain (see section on direct and indirect effects above), the less hard the proof of effects of CIB can be, as other elements and/or events are causing elements, too . Therefore, I propose to support my search for the effects of CIB through a medium level of abstraction that balances analytical detail without losing the entire picture. First, to deal with the *complexity* of the causal situations of combined scenario methodologies, I propose to analytically divide idiosyncratic methodologies into the different elements at play, using the framework on transdisciplinary methodologies presented in section 4.1. Second, to deal with the *length* of the causal chains, I cut the analyzed processes into tranches, using the phases of the process model of CIB&S processes presented in section 4.2.1 for orientation.

Per phase of a CIB&S process, I propose to proceed in three steps:

1) Describe the methodology: What (sub)activities are impacted by what interplay of what methods and techniques, actors, data and under what conditions (characterizing the potential *independent* categories)?
2) Asses the levels of traceability and consistency and of further (unintended) outcomes with regard to the process and products (i.e. characterizing the *dependent* categories).
3) By interpretation, establish (qualitatively) plausible (causal) links between the levels of traceability and consistency (and other outcomes) and the methodology by argumentatively separating influences of CIB, its interplay with other elements and the (independent) impact of

other elements. Provide plausible descriptions of the effects: What happened? Why? What are effects of CIB, what are effects of other methodological elements? Why did effects (not) occur?

Overall, I am stretching the framework by Hinkel from a visualization technique for transdisciplinary methodologies to a tool that supports the tracing of effects of specific elements of the methodology and of their interplay. The empirical application will show, to what degree this is useful.

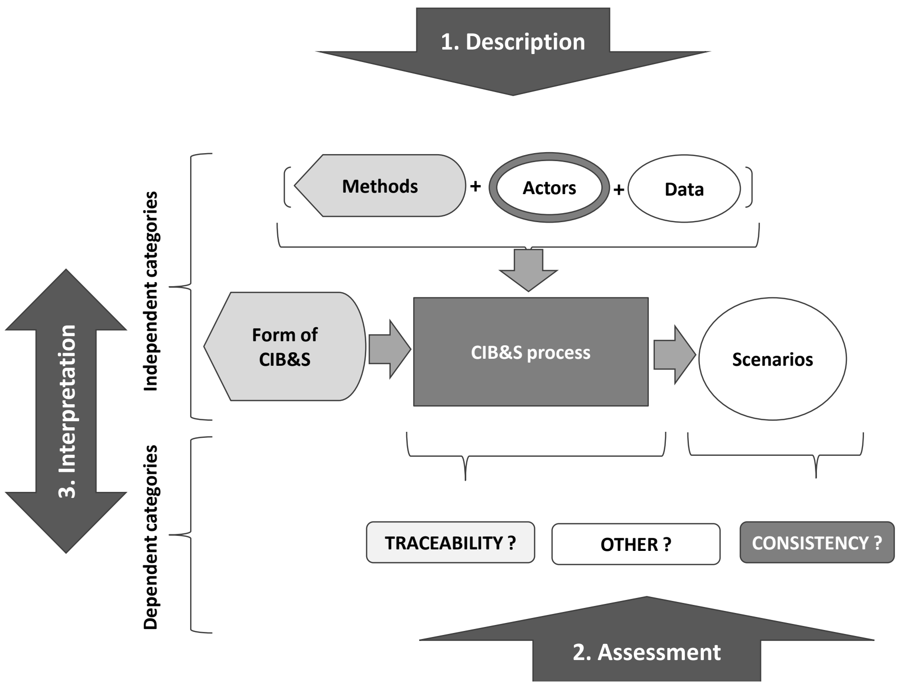
4.5 Scope, research questions and expectations

In this section, I summarize the scope of the analysis (4.5.1). Based on the foregoing conceptual considerations, I refine the research questions (4.5.2) and make my expectations explicit (4.5.3).

4.5.1 Visual summary of the scope of the study

Figure 11 gives an overview of the scope of the study, putting together the different conceptual elements developed in this chapter. These conceptual elements make it possible to look for intended and unintended effects of *CIB* within specific methodologies, which are characterized by particular social organizations, technical designs and cognitive settings, by specific forms of the combination and by specific conditions. They also permit the to examine the effects of *other* methodological elements and of their interplay with CIB.

Figure 11: Overview of the scope of the study



Please note that even if scenario traceability tends to be associated with the scenario *processes* and scenario consistency rather with the scenario (and model) *products*, the division into process and products is an analytical one. Processes and products are inextricably linked and this challenges their analysis. It is not possible to fix processes, since when you observe them you transform them into products (e. g. into observation protocols). In short, the effects of CIB&S methodologies are produced during activities (i.e. processes) but then manifest themselves in their products. In sum, the consistency of scenario products is constructed through scenario processes, and the traceability of the scenario process shows up in the scenario products.

4.5.2 Research questions

The overall research question of this study, reformulated in line with the conceptual considerations of this chapter, is the following: *(How) can the use of CIB within combined scenario methodologies (especially of the CIB&S-type) support inter- and transdisciplinary research groups to construct qualitative <u>and</u> quantitative or integrated scenarios of socio-environmental systems?*

This chapter has pointed to conceptual ideas on different forms, in which CIB could be combined with numerical modeling and simulation and to potential effects of the use of CIB in such scenario methodologies regarding scenario traceability and scenario consistency. In the following, three research questions are detailed to guide the empirical analysis.

Question 1 (forms of CIB&S): In what forms can CIB be combined with simulation models to support interdisciplinary research groups to construct qualitative *and* quantitative and/or integrated exploratory scenarios of socio-environmental systems?

How can the form of combination of the two components, the CIB and the simulation models, be (effectively) designed, considering the type of system representations by the CIB and by the numerical model(s); the relative positions of both components within the process; and the type and degree of link between the two?

Question 2 (effects of CIB&S): What effects does the use of CIB in combination with simulation models (type CIB&S) have on scenario traceability and scenario consistency? What are other (unintended) effects?

What effects does the use of CIB have on scenario traceability, especially with regard to the traceability of a) assumptions on future developments and b) their interrelations; c) the composition of individual scenarios and d) the selection of the scenario sample? What effects does the use of CIB within combined scenario methodologies have on scenario consistency? What effects does it have when it comes to the internal consistency of different forms of scenarios (raw CIB, narrative, numerical, integrated ones); on the consistency between qualitative and numerical forms of scenarios (input data sets plus model outputs); and finally, on the consistency between the underlying conceptual and numerical models (comparing system boundaries, system elements and (inter)relations)?

The use of CIB within combined approaches (type CIB&S) is considered in a perspective of propagation: What happens to the (supposed) traceability and consistency gains that are introduced through the CIB into a combined scenario methodology? Are these gains effectively achieved and if yes, are they also handed down through the entire combined scenario process? What direct and indirect effects does CIB have on a combined scenario process beyond the activity of qualitative scenario construction with CIB?

And overall, what are other (unintended) effects of the use of CIB within combined scenario methodologies?

Question 3 (influencing factors): How are theses outcomes of the use of CIB influenced by other factors, namely by characteristics of the methodology and by the form of CIB&S?

Bringing the different dimensions under study together, namely effects of CIB, the influence of the specific methodologies and the influence of the individual forms of its combination, I ask: How and to what degree are the effects and functions of CIB linked to the characteristics of the specific methodologies and to the forms in which CIB is combined with simulation models?

4.5.3 Expectations

This is an exploratory study. That means no fix hypothesizes are available that could be tested. However, in the process of reviewing the literature and building the conceptual framework, I developed specific expectations that I now make explicit. The overall expectation for the use of CIB within combined scenario methodologies is as follows.

4.5.3.1 Overall expectation

Overall:[148] When CIB is used as the qualitative scenario method in combined scenario methodologies, the properties of CIB (compared with e. g. Intuitive Logics) have supporting effects on scenario traceability and scenario consistency across the entire combined process and on different types of scenario products. These effects depend on the individual form of combination of CIB with simulation models (CIB&S) and on other characteristics of the individual methodological design of each CIB&S process (i.e. the interplay of further methods, actors and data (in the widest sense) and their specific conditions).

In the following, more detailed expectations are presented on effects on scenario traceability (expectations “T”); scenario consistency (expectations “C”), other effects (expectations “X”), the role of the form of combination (expectations “F”) and the role of further characteristics of combined scenario methodologies (expectations “R,” with R standing for “rivals” as in Yin (2009), see chapter 5).

[148] See also the basic assumptions A1 and A2 presented in section 4.4.1.

4.5.3.2 Expectations "T": effects of using CIB within combined scenario methodologies on scenario traceability

The literature suggests that the CIB method properties have supporting effects on the scenario traceability of qualitative raw CIB scenarios as perceived by internal and externals as well as by experts and laypeople. In addition, I expect that in combined scenario methodologies, these traceability effects propagate to further forms of scenarios as storylines as well as numerical scenarios.

Expected traceability effects of CIB on the construction of raw CIB scenarios

E 1 Traceability of assumptions on future developments: If D&V are distinctly defined, then future developments assumed in the CIB raw scenarios are made explicit and accessible for internal and external users as well as for experts and laypeople.[149]

E 2 Traceability of assumptions on interrelations: If direct hindering and promoting effects between future developments are assessed pairwise and stored in a full CIB matrix, then assumptions with regard to the interrelations between future developments are made explicit and accessible for internal and external users in the form of a conceptual CIB model.

E 3 Traceability of individual scenario composition and of sampling: If a (any) systematic and formal approach is chosen to select scenarios, then the scenario selection, at least is in theory, is transparent for and even reproducible, at least by those internal and external users, who are able to work with the selected algorithm or software applied (i.e. experts). If the specific CIB algorithm is chosen to select scenarios, then the scenario selection is not only in theory transparent for and reproducible by internal and external users, but in addition, the justification for or against the choice of a scenario can in practice be easily checked by pen and paper even without deeper method or software competencies (i.e. also by laypeople).

In sum, these expectations E1 to E3 describe the expected benefits of CIB compared with more intuitive approaches of qualitative scenario construction and selection—quite independently of the use of CIB within combined approaches or separately as a stand-alone approach. Within *combined* scenario methodologies, I expect further direct and indirect traceability effects through the use of CIB:

Expected traceability effects of CIB within combined methodologies on further scenario products

E 4 More traceable storylines: If CIB scenarios and the information on interrelations of future developments of the CIB matrix are comprehensively and adequately (i.e. following the CIB definitions and assumptions) used as a basis from which to write storylines, then the storyline writing can benefit from the same traceability effects as the CIB raw scenarios (E1 to E3), namely the traceability of as-

[149] This is no unique effect of the use of CIB but an expected effect when using any other systematic scenario technique, too.

sumptions on future developments and interrelations as well as the traceability of the construction of individual scenarios and samples. In sum, the use of CIB (indirectly) brings more scenario traceability into the storylines.

E 5 More traceable numerical input data sets (level I) (first half of the numerical scenarios): If during matching (level I), the selected CIB scenarios are (adequately)[150] translated into numerical input data sets for model runs, then these numerical input data sets can benefit from the verbal explicitness of the assumptions on future developments and on their interrelations; and the sample of the numerical input data sets can benefits from the transparent and systematic definition and scenario selection with CIB. In sum, the use of CIB is expected to (indirectly) bring more scenario traceability into the input data sets of the numerical model(s).

E 6 More traceable (numerical) model structures (level II) and simulation outputs (level III) (second half of numerical scenarios): If the assumptions stored in a conceptual CIB model (on central system elements, their future developments and their interrelations) are, in contrast to implicit mental models, openly (and reciprocally) compared with the assumptions made by the respective numerical models (on central system elements, their future developments and their interrelations), then this matching on level II is opening a window onto the logic of the numerical simulation model. In sum, this comparison of (conceptual and numerical) model assumptions is expected to support the traceability of internal model assumptions (level II) and potentially also of the logic behind the calculation of model outputs (level III).

4.5.3.3 Expectations "C": effects of using CIB in combined scenario methodologies on scenario consistency

With the CIB balance algorithm, an additional consistency criterion is introduced into combined scenario methodologies—considering that actors' subjective consistency perceptions as well as mathematical models are consistency methods, too. I assume that through the use of CIB, internally consistent raw CIB scenarios become a part of the methodology; and I expect that CIB consistency effects might propagate to further forms of scenarios as storylines and numerical scenarios.

Assumption for the consistency of raw CIB scenarios

A 3*:* I assume that if CIB is used to construct qualitative scenarios then these raw CIB scenarios are internally consistent in accordance with the CIB consistency criterion; and scenario samples based on the same CIB matrix are consistent within themselves.

[150] I.e. following the CIB's definitions and assumptions.

Expected consistency effects of CIB within combined methodologies on further scenario products

E 7 More consistent storylines: If the storyline writing based on the CIB raw scenarios is adequate (meaning that it follows the CIB definitions and assumptions), then the CIB scenarios hand down their internal consistency and the consistency within the scenario sample to the qualitative storylines and furthermore, consistency between raw CIB scenarios and qualitative storylines is given.

E 8 More consistent numerical input data sets (level I) (first half of the numerical scenarios)**:** If quantification and specification of the raw CIB scenarios into numerical input data sets (during matching on level I) are adequate (that is, they follow the CIB definitions and assumptions), then the CIB scenarios hand down their internal consistency and the consistency within the scenario sample to numerical sets of input data; and consistency between the CIB scenarios and the numerical sets of input data (the first half of the numerical scenarios) is given.

E 9 More consistent model structures (level II): If the model structures (concerning central system elements and their interrelations) of the CIB conceptual model and of the numerical model underlying the scenarios are compared, oriented and adapted to each other (during matching on level II), consistency between underlying models is supported.

E 10 Third order effects of CIB on the consistency of simulation outputs (second half of numerical scenarios)**:** Simulation outputs are by definition internally consistent according to the consistency criterion of the numerical model and consistent with the simulation model's input data and parameter settings (first half of the numerical scenarios). Still, third order consistency effects of CIB on simulation outputs are expected, namely those that occur through matching on level I (definition of model input and restrictions, see E 8) and through model comparison and adaptation with regard to future assumptions, system elements and interrelations (matching on level II, see E 9).

4.5.3.4 Expectations "X": other effects of CIB

E 11 Other effects: It is expected that using CIB within combined scenario methodologies might have further, potentially unintended, effects. These are not specified but left open to the empirical exploration.

4.5.3.5 Expectations "F": the role of the form of the combination for effects of CIB

E 12 Role of the form of the combination: The effects of the CIB within combined scenario methodologies are expected to depend on the *form* in which CIB is combined with simulation models concerning system representations, position and link.

E 12a System representation: The more overlap between scope and detail of the system representations of the CIB and of the numerical simulation model, the stronger the effects of the CIB on the combined process and its scenario products.

E 12b Position: The stronger the position of the CIB in the hybrid methodology compared with the position of the numerical simulation model (especially with regard to timing and dominance), the stronger the effect of CIB on the combined process and its products.

E 12c Link: The closer the link (especially with regard to structure and degree of coupling and iteration) of the CIB with the numerical simulation model, the stronger the effect of CIB on process and products.

4.5.3.6 Expectations “R” (rivals): the role of further characteristics of the individual methodological design of each CIB&S process for effects of CIB

E 13 Rivals: The expected traceability and consistency effects of CIB can be hindered or mediated through the interplay with other elements of the individual CIB&S methodologies, as specific constellations of actors, other methods, data and conditions during the different activities of a combined scenario process. I expect that the *social organization* of the combined scenario process (for example, who is doing/deciding what?; the inclusion of actors in different activities, responsibility, power, trust and support, initiative etc.) and the *technical design* of the process (for example, what concrete methods and techniques are applied during the CIB, for matching, modeling, facilitation, documentation?) play a role.

To confront the expectations with empirical evidence, case studies have been set up. In the following chapter, their empirical design is presented.

Chapter 5: Design of the empirical study

This chapter documents the design of the empirical part of this study. The study is exploratory in nature, as it aims to analyze a new and still poorly understood combined scenario approach. Its central question is an '(if and) how'- question. The empirical part of the study has descriptive elements but also aims to establish the patterns of effects that the use of CIB has in different forms of its combination with modeling and simulation. This study is doing so in a qualitative way. Based on the description of methodologies and the assessment of outcomes, it aims to propose plausible explanatory elements by means of interpretation. Therefore, the study uses the "set of conceptually specified analytic categories" (cf. Huberman/ Miles 1994: 431) developed in chapter 4. It is based on explicit expectations for the use of CIB within combined scenario methodologies. It is hypothesis generating rather than hypothesis testing.

I attempt to take over the research perspective of a reflective foresight practitioner,[151] as stipulated by van't Klooster and van Asselt (2006) and further elaborated by van Asselt and colleagues (2010).[152] I am not—not even trying—to assume a complete outsider perspective, as authors in the tradition of quasi-ethnographic research on foresight have attempted to (cf. e. g. van Asselt et al. 2010). Nor am I dealing with method development without explicit and conceptually based reflection, as it is frequently practiced in futures studies and foresight. Instead, I am using my insider perspective to gain insight into a specific scenario practice. From this perspective, I am not neutral, but instead, believe in what I am doing. I am positively biased in favor of the use of CIB. But then I take a step back to reflect on and conceptualize my insights and experiences from a more neutral position, to finally turn back to the inside to inform scenario practice. The case study approach is applied to systematically and transparently describe, analyze and reflect upon the first empirical experiences of using CIB in combined scenario methodologies in the field of socio-environmental scenarios. The deep empirical analysis of this study was possible only *because* I was involved in the cases myself and because they were co-shaped by my methodological research interests.

In the following, first I introduce the case study approach of this study (5.1). Second, I design, delimit and justify two empirical cases; I document my access and roles a; and specify the respective research questions. The first case (UBA) is a demonstrator application of CIB to construct framework data sets for a group of environmental models (5.2). The second case (Lima Water) is a pioneer application of CIB within a combined scenario process resulting in integrated (qualitative-quantitative) scenarios on Lima's water futures 2040 (5.3). Fourth, I document the data collection in both cases

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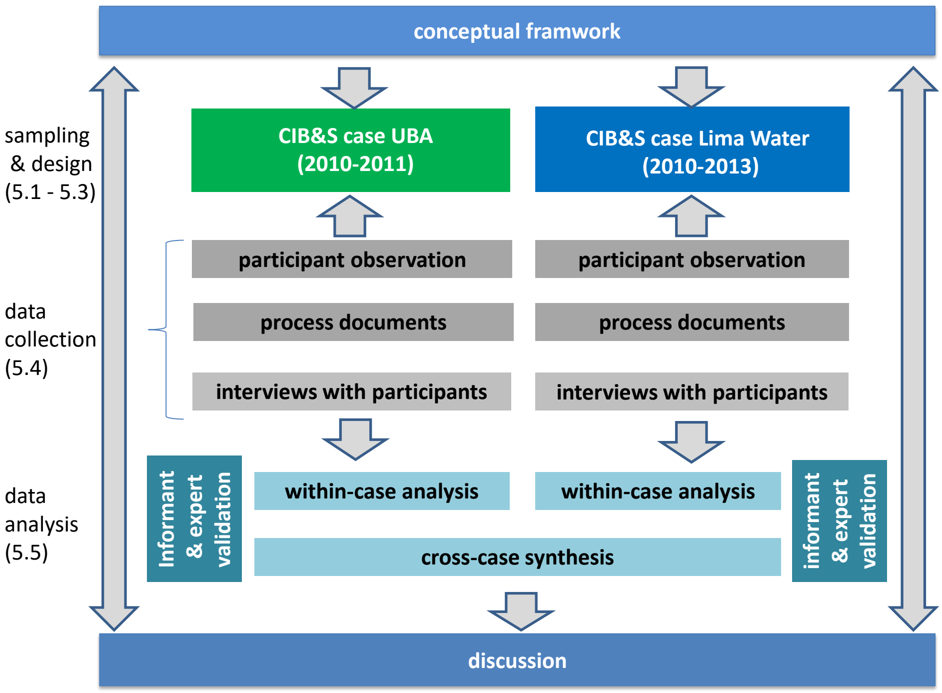
151 With reference to the book "the reflective practitioner" by Schön (1984).

152 Another attempt to promote this position, focusing on the practical side and the users' perspectives in foresight, has recently been made by Kunseler and colleagues (2015).

(5.4). Fifth, I present the strategies of qualitative data analysis of the individual cases and of the cross-case synthesis. Both include forms of communicative validation (5.5). Finally, I discuss the quality of the design, of the collected data and of the empirical findings of this study (5.6). Figure 12 gives an overview of the design of the empirical part of the study and shows, how it is embedded in the overall study.

Figure 12: Overview of the empirical design of the study



5.1 Designing two exploratory case studies

In this section, I first give a brief introduction to case study research (5.1.1) and then specify the design of this study using two exploratory case studies on CIB&S (5.1.2).

5.1.1 Case study research

Case study research is an approach of the social sciences[153] to phenomena that require an "in-depth description" (Yin 2009: 4 ff., also for the following). It is not so much a method as a research perspective,[154] which is associated with empirical, often problem-oriented and mostly qualitative research. Since the 1980s, it was described, and further developed and established—by Robert K. Yin, among others. Case study research is often presented in explicit distinction from ethnographic approaches (e. g. Yin 2009: 15) and with a tendency to transfer academic principles, formalized and systematic approaches to the study of the social world (cf. e. g. Yin 2009, Miles/ Huberman 1994, Scholz/ Tietje

153 It is applied in very different disciplines from psychology through education, sociology, law, and medicine to business (cf. Yin 2009).

154 And its practical application results in methodologies as defined by Hinkel (2008).

2002). Yin specifies that case study research is appropriate (cf. 2009: 10) to answer how and why questions (instead of who, how many and how much?), and especially when there is little control over contemporary, social events.

Case study research is also used in inter- and transdisciplinary environmental research, albeit in a slightly different way, to deal with the idiosyncrasies of empirical situations (cf. also in the following Scholz and Tietje 2002). Environmental case studies are conducted with the aim of gaining an understanding of complex and so-called ill-defined situations, such as situations with uncertain states, mechanisms and outcome which are typical for problem-oriented, applied and interdisciplinary research. Case studies are used in this field not only to analyze situations but also to achieve synthesis (cf. Scholz/ Tietje 2002).[155]

Case study research according to Yin (2009) is characterized by four *principles*. First, “case studies, like experiments, are generalizable to theoretical propositions and not to populations or universes” (Yin 2009: 15). Second, before data is collected, it is necessary to define theory-based propositions or at least purpose and the criteria by which to measure success (cf. Yin 2009: 28). Third, to identify cause-and-effect relationships within individual or across a few cases, it is essential to identify and to address so-called rival hypotheses, i.e. to consider all possible (alternative) explanations.[156] Fourth, ideally, replication is used to guide the analysis. Literal replication is applied when, in more than one case, the same results are expected; or theoretical replication is applied, when, for theoretical reasons, different outcomes are expected in different cases.

Types of case study design can be distinguished in *single case designs* dealing with critical, unique, extreme, typical, revelatory or longitudinal cases (cf. Yin 2009: 47 ff.) vs. *multiple* case designs, applying replication logic (cf. above). In multiple case designs, each case is first analyzed for itself (*within-case* analysis), then in a *cross-case* analysis, situations, logic and effects are compared and findings synthesized. Cases are considered *holistic* if the case itself is the only unit of analysis, and *embedded* when they comprise different units of analysis (Yin 2009: 29, Scholz/ Tietje 2002).

The research process in case study research consists of typical *phases*. Yin (2009) proposes the following six: First, the researcher needs to decide and to justify why (s)he uses the case study approach. Second, during sampling and design, the cases and the logic of the design need to be defined, including the research questions, propositions, units of analysis etc. Third, a case study protocol has to be prepared for every single case. The purpose of the protocol is to guide the investiga-

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155 In sum, even if the understandings diverge a little, case study research has the advantage that it is at the same time a well-established social sciences method, i.e. corresponding to my primary academic socialization as a social scientist, and also can be connected to the current practice of (future oriented) environmental research, which is one of the main audiences targeted by this research.

156 For an overview of different types of rivals, see Yin (2009: 135).

tor through every individual case and to structure a focused data collection of the individual case.[157] The protocol contains the data collection instrument(s) as well as the procedures and general rules to be followed during the case study.[158] Fourth, the case study evidence (generally from different sources) is collected. Fifth, the case study evidence is analyzed. Finally, the findings from the case study are summed up in a case report.

Case study research was suspected of being a label for bad research, or studies without a clear design (cf. Yin 2009 14 ff.)—and indeed, there are important *limits* to case studies and threats to their quality. The most important limit is that case studies allow theoretical but no statistical generalization (cf. above.) Central threats to quality are (cf. Yin 2009, Scholz/ Tietje 2002) a mismatch between the definition of the cases and the research questions, i.e. when the empirical cases are not chosen in such a way that they can appropriately answer the research questions. Also, good case study research is hindered by a lack of rigor, non-systematic and non-transparent approaches, and through insufficient resources.[159] Another aspect seen critically by some is the “interactional resonance” (Scholz/ Tietje 2002: 18), which means that the analysis of the case influences the case itself. Yin (2009: 112) is more positive towards this phenomenon in terms of voluntary and explicit manipulations, as these “can produce a greater variety of situations for the purpose of collecting data.” Still, issues of role conflict can arise, when the researcher mixes his or her different roles. On the upside, case study research offers the opportunity to systematically, comprehensively and deeply analyze and interpret complex social phenomena in their real world settings.

5.1.2 Designing case studies on CIB&S methodologies

In this study, the case study approach was considered the most appropriate empirical approach to the focus of this study and its research question, which is centrally a how-question. The use of CIB by interdisciplinary research teams within combined scenario methodologies can be understood as a social phenomenon, even if it takes place within the social subsystem of research, and it is something people are doing. Case study research was perceived as an adequate means to methodologically support the research position of the reflective foresight practitioner. CIB&S processes are considered complex idiosyncratic configurations of multiple methods, actors and data. Controlling these system-

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157 “The protocol is a major way of increasing the reliability of case study research” (Yin 2009: 79).

158 More precisely, Yin argues, the protocol has to cover the following four aspects (Yin 2009: 81ff.): Overview of the case study project (context, purpose, setting and propositions), field procedures (concerning data collection, including access and resources), the case study questions and a ‘tentative outline’ of the later case study report. At the same time, he admits that some flexibility in the case study plans can be necessary after the first data collection, and that the case study approach allows the use of this flexibility (cf. Yin 2009: 90).

159 For instance in terms of investigator skills, but also in time and money, as well as regarding access to and cooperation with case members.

atically in the form of (quasi) method-experiments or method-tests, is considered difficult due to their complexity, their low level of conceptualization and their duration.

Overall, these case studies on CIB&S are *exploratory*, but also contain descriptive and even explanatory elements.[160] Two empirical cases are used to explore possible forms of the combination of CIB within integrated scenario methodologies; to describe their empirical effects, and to identify factors causing these effects. Both cases are embedded in the contexts of applied and interdisciplinary research projects carried out by ZIRIUS at the University of Stuttgart. Case I, in the following the *UBA case*, is a first *demonstrator*. Case II, in the following the *Lima Water case,* is a full *pioneer application*. The cases are further defined in sections 5.2 and 5.3.

Both cases can be considered unique and new cases (as described by Yin 2009). I chose them because, at the time this study started, to my knowledge they were the only ongoing (and accessible) CIB&S cases. The sampling of the cases is not a multiple case design as Yin would describe it, since no *replication* logic was applied. I expected neither similar nor, for theoretical reasons, contrary results. Rather, the two cases are empirical representatives of a larger spectrum of possible—but not yet realized—forms of the use of CIB within integrated scenario methodologies—as it were, two spotlights into the dark. The later analysis will argue that both cases can be considered *revelatory* and *typical* cases with regard to their aim and their form, in which CIB is combined with simulation (cf. chapter 8). The overall unit of analysis is the combined CIB&S scenario process and its results. The perceptions and assessments of this process through its participants are considered separate, embedded units of analysis.

5.2 The UBA case—a demonstrator

In this section, I distinguish the UBA case from its contexts (5.2.1); and define and justify it (5.2.2). I document my access to and roles within the case (5.2.3), and specify its research questions (5.2.4).

5.2.1 Contexts

In case studies, "the boundaries between phenomenon and case are not clearly evident" (Yin 2009: 18). Figure 13 gives an overview of the UBA case, distinguishing its phenomenon from its different contexts.

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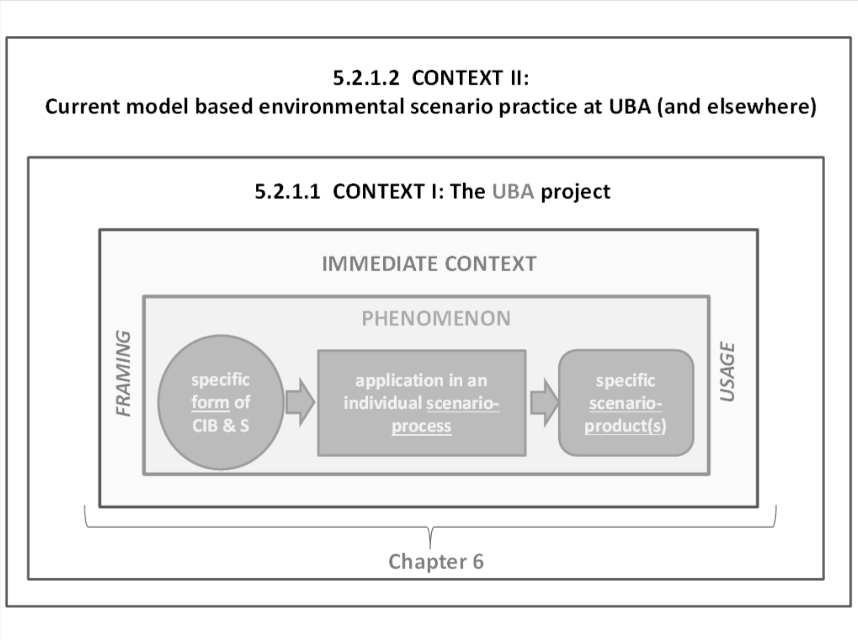
[160] Case study research can be used for different epistemological aims (cf. Yin 2009: 7 ff.). Exploratory case studies are used to gain insight to the structure of a phenomenon and to develop hypotheses or theories. In descriptive case studies, theories are used to describe a case; explanatory case studies focus on qualitative theory testing, relying on hypotheses [or: a hypothesis] formulated before data collection.

Figure 13: Overview of the UBA case: The phenomenon and its contexts



I distinguish between the *phenomenon* and its *immediate* context (that is the framing and usage phases), which are both subject of the empirical study (cf. case report in chapter 6). I analytically distinguis these from the *broader* contexts of the case, namely the so-called UBA project (5.2.1.1), which in turn needs to be considered against the background of current model-based environmental scenario practice (5.2.1.2).

5.2.1.2 The research project "consistent and harmonized framework assumptions"

This case study takes place in the context of a research project conducted by ZIRIUS. The project was named "Consistent framework assumptions informing model- and scenario-analysis at the German Federal Environment Agency (*UBA* or Umweltbundesamt).[161] The project was funded by the UBA, and thus by public means.[162] In September 2010 the UBA, or more precisely the Department for Fundamental Aspects, Sustainability Strategies and Scenarios, Sustainable Resource Use,[163] had published a call for a special report providing the UBA with consistent and plausible framework data sets to ensure the quality of environmental modeling (aim 1) and to enhance the comparability of (model-based) scenario studies at the UBA (aim 2). The report was to develop consistent sets of framework data, including time series for the model input parameters. ZIRIUS, which is to say two of my colleagues and I, wrote a proposal, and were asked to carry out the project, which was launched in October 2010.

161 ZIRIUS project, funded by the German Federal Environment Agency (UBA) (2010). For more information on the project please visit: URL: http://www.zirn-info.de/projects_e/x_konsistenterahmendaten.htm.

162 The UBA is an agency for administration and research that belongs to the Federal Ministry of the Environment (BMU, Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit). The UBA can thus be considered a boundary organization between research and policy.

163 Abteilung für Grundsatzfragen, Nachhaltigkeitsstrategien und -Szenarien, Ressourcenschonung.

We had proposed using CIB to develop several consistent sets of framework assumptions illustrating the range of different potential developments of socio-economic and political contexts for environmental modeling and model-based scenario studies at the UBA. The project comprised two phases (for more detail, see also UBA case protocol, Supplement A):

- Phase 1: Identification of relevant framework issues: selection and definition of key factors and of their alternative developments
    - Step 1: Selection of material for the identification of key factors
    - Step 2: Selection of relevant key factors
    - Step 3: Development of key factor briefs and definition of possible alternative developments
- Phase 2: Interrelations and plausibility check: construction of consistent context scenarios with CIB
    - Step 1: Cross-impact balance analysis
    - Step 2: Analysis and preparation of consistent framework scenarios, underpinned with time series

The project ran from October 2010 (kick-off workshop) to January 2011 (final workshop). A final special report was published in February 2011 (cf. Weimer-Jehle/ Wassermann/ Kosow 2011). The project was carried out jointly by ZIRIUS and the UBA project manager, supported by several joint meetings at the UBA. Furthermore, the project involved a panel of internal experts from the UBA. In sum, the UBA project was a small inter- and transdisciplinary and method focused project.

5.2.1.2 Background: current model-based scenario practice

The background of the project call was the perception of responsible actors at the UBA that a multitude of different model-based environmental studies coexist, at the UBA and elsewhere. In January 2010, 17 different mathematical models were in use in UBA-funded research projects for environmental modeling and model-based scenario building. These mostly sectoral models covered issues as divergent as transport, energy, water, and sustainability in general. These models made diverging assumptions on future developments (by using a range of different time series as input data) and resulted in a range of different results that are difficult to compare—as they were based on different models *and* on different input data assumptions. The aim of the UBA actors thus was to ensure the quality of scenario studies and to make the diversity of (framework assumptions of) quantitative model-based scenario studies at UBA more comparable.[164] In the special report resulting from the project, consistent sets of framework data should be developed and underpinned with time series. Furthermore, method interest by the UBA and by ZIRIUS, and especially by me was an important context factor which is dealt with within the immediate context of the case (see the section on framing in Chapter 6).

[164] Note that the explicit aim of the UBA was to increase the comparability of framework assumptions—but not to ensure their complete harmonization within this short project.

5.2.2 Definition and justification

The UBA case is closely related to but not completely identical with the UBA project. The UBA case focuses on the use of CIB in combination with environmental simulation models to construct socio-environmental scenarios, i.e. on a form of CIB&S. The *phenomenon* under study in the UBA case is the process of using CIB in its specific combination with numerical modeling and simulation models in the UBA project by an inter- and transdisciplinary team.

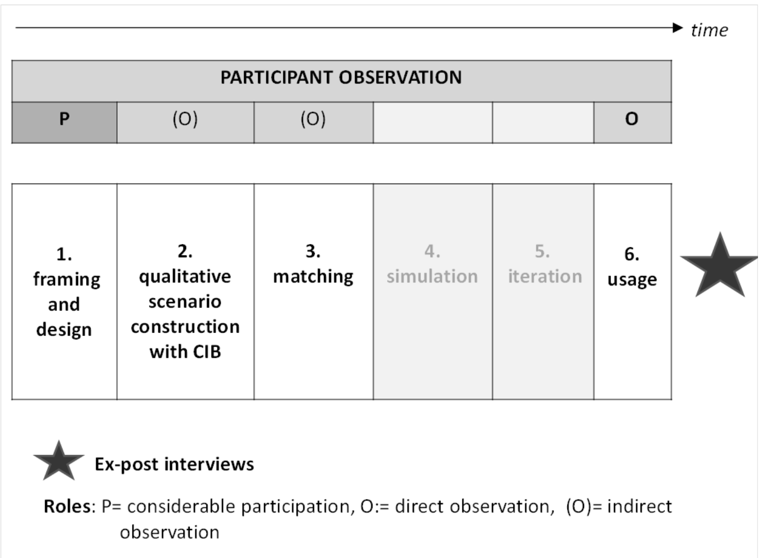
In the UBA case, no full CIB&S process was carried out. No actual modeling or simulation with the newly constructed input data sets was foreseen or carried out within the demonstrator project. Nevertheless, this is a *relevant* case, since CIB is used in relation to numerical modeling and simulation; and because it leads to CIB based numerical input data sets on societal contexts for environmental models. I divide the case into the combination that was *in fact* realized during the demonstrator and that form of combination of CIB with a group of models that was *hypothetically* considered and anticipated during the exercise (cf. framing in Chapter 6). I consider that the actual form of application enables us to learn about the hypothetical (full) form(s) of application. In the following, the effective and the hypothetical dimensions of the case will be discussed separately and the empirical case will be characterized as an CIB(&S) case.

The case study started with the call for tender in September 2010, and data collection was completed with the interviews with process participants in March and July 2011. The runtime of the case study was thus longer than the runtime of the UBA project.

5.2.3 Access and roles

Figure 14 shows my involvement in the UBA case.

Figure 14: My access to and impact on the combined scenario construction process (UBA)



I was heavily involved in writing the project proposal and thus also in designing the scenario process of the UBA project. Therefore, I had the status of a project member within the project in the role of a CIB scenario expert. The occasion to carry out the UBA project and case came quite spontaneously. Therefore, during parts of the UBA project runtime, I was in the USA for a research stay and was back in Germany for the final workshop and the reporting phase only. Thus, part of the process took take place without my being able to observe or to participate directly. But close communication about the projects progress was ensured between me and my colleagues, who took over the conduct of the CIB analysis. In addition, I had access to the key participants from UBA during interviews. This was made possible through the UBA project manager who, when informed of my research interest, supported me by formally inviting them. During the interviews, the UBA process participants were informed of my PhD project and were asked for their consent.

In sum, in the UBA case I had a double role. On the one hand I was in the role of a UBA project team member, and in this role mainly participating in the framing and reporting. On the other hand I was in the role of a method researcher doing her PhD, taking the perspective of an observer, archivist and interviewer.

5.2.4 Specifying the research questions

To focus the empirical analysis, the research questions to the UBA case have been specified.

(How) does the use of CIB within the specific combined scenario methodology of the UBA case support its interdisciplinary research team to analyze and compare numerical model inputs used at the UBA and to provide joint framework data sets?

1. In what *form* of combination is CIB used in the UBA case to construct consistent sets of framework assumptions for environmental modeling and model-based environmental scenarios at the German Federal Environmental Agency? (*form of CIB&S)*
2. *What effects* does the use of CIB within the specific combined scenario methodology of the UBA case have on scenario *traceability* and scenario *consistency*? What are further (unintended) effects? *(outcomes*)
3. *How* are outcomes of the use of CIB *influenced* by other characteristics of the specific *scenario methodology* and by the specific *form* in which CIB is combined with numerical simulation models in the UBA case? (*factors*)

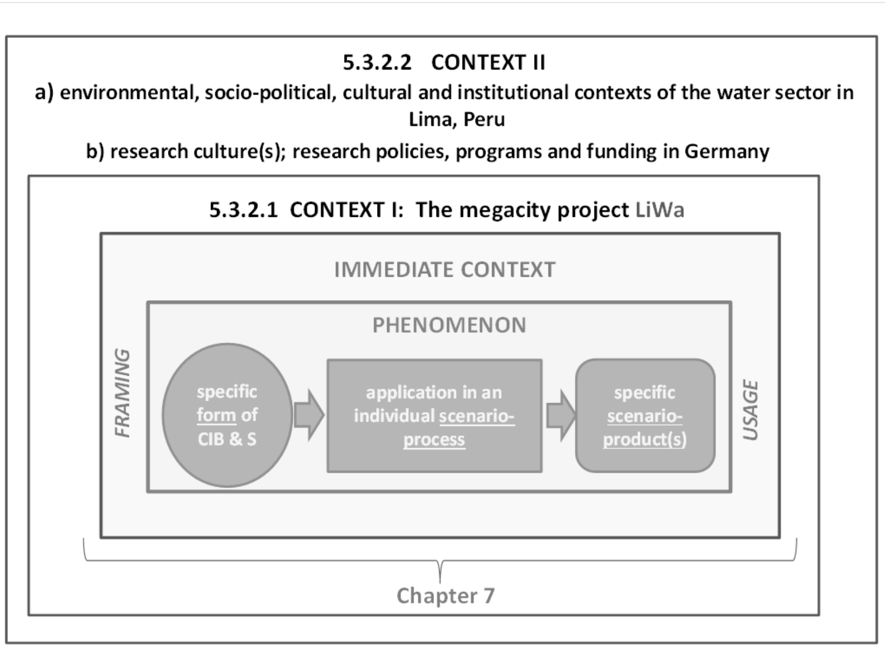
5.3 The Lima Water case—a pioneer application

In this section, I distinguish the Lima Water case from its contexts (5.3.1); and define and justify the case (5.3.2). I document my access to and roles within the case (5.2.3) and specify its research questions (5.2.4).The presentation in parallel to the UBA case is chosen to support the comparison of the cases by the reader.

5.3.1 Contexts

Figure 15 gives an overview of the 'Lima Water case', distinguishing its phenomenon from its different contexts. I distinguish between the *phenomenon* and its *immediate* context (the framing and usage phases), which are subject of the empirical study (cf. case report in chapter 7). Furthermore, I divide the broader contexts of the case into the project context within the megacity project LiWa (5.2.1.2), which in turn is embedded in the bigger picture of environmental, socio-political, institutional and cultural Peruvian contexts in the water sector in Lima and in German research culture(s) and programs (5.2.1.2). In the following, these contexts are presented only to the degree necessary to understand the case.

Figure 15: Overview of the Lima Water case: The phenomenon and its contexts



5.3.2.1 The megacity LiWa project

In the Lima Water case, CIB is combined with simulations within the transdisciplinary and applied research project, "Sustainable water and wastewater management in urban growth centers coping with climate change, concepts for metropolitan Lima (Peru)" (LiWa).[165] The project was publicly funded by the German Federal Ministry of Education and Research (BMBF, Bundesministerium für Bildung und Forschung).

The overall *aim* of the LiWa project is stated on the project website as follows:"The LiWa project particularly focuses on the development and application of fundamental procedures and tools for participatory decision making, based on informed discussions." [166]

To reach this aim "the project builds upon *modelling* and *simulation* of the entire water supply and sanitation system within the urban growth centre system of Lima" (my emphasis).[167] It is an explicit aim of the project to develop "methods and tools […] to analyse a life-line system"[168] that can be transferred to other contexts. Method development was at the centre of the LiWa project.

From 2008 to 2013, the LiWa project was conducted by twelve cooperating partners from Peru and Germany, including mainly research and education institutions but also stakeholders as the major water utility company of Lima, NGO partners and SME representatives.[169] The core of the LiWa team comprised around 20-25 people and on average, from each partner, two worked on the LiWa project fairly constantly.

The project dealt with various aspects of the management of the drinking and waste water system of Lima and Callao, Peru, covered by various work packages comprising, among others, qualitative sce-

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165 ZIRIUS project together with several partners, funded by the German Federal Ministry of Education and Research (BMBF) (2008-2013). For more information on the project please visit: www.lima-water.de.

166 Source: project website, URL: *http://www.lima-water.de/en/index.html?Menu=2.*

167 Ibid.

168 Ibid.

169 *German Partners:*

- Ifak, Institut für Automation und Kommunikation e.V., Magdeburg (Project coordinator)
- ZIRIUS, Center for Interdisciplinary Risk and innovation Research, University of Stuttgart (coordinator Peru)
- IWS, Institute of Hydraulic Engineering, Chair of Hydrology and Geohydrology, University of Stuttgart
- ILPOE, Institute of Landscape Planning and Ecology, Faculty of Architecture and Urban Planning, University of Stuttgart (since 2011)
- UFZ, Helmholtz Centre for Environmental Research (UFZ), Department of Economics, Leipzig/Halle
- Ostfalia University of Applied Sciences, Suderburg
- Dr. Scholz & Dalchow GmbH

Cooperating Partners in Peru (financially involved):

- SEDAPAL Servicio de Agua Potable y Alcantarillado de Lima
- FCPV, Foro Ciudades para la Vida, Lima
- UNI, Universidad Nacional de Ingeniería Lima
- FOVIDA, Fomento de la Vida, Lima
- IMP, Instituto Metropolitano de planificacion (since 2012), Lima

Associated Partners in Peru:

- SENAMHI, Servicio Nacional de Meteorología e Hidrología
- SUNASS, Superintendencia Nacional de Servicios de Saneamiento

nario building as well as numerical model building and simulation.[170] For more detail on the different work packages and their products, please see the project website[171] as well as Schütze (2015).

Overall, the LiWa project was an *applied* and *problem-oriented research* project in which *interdisciplinary* systems knowledge was required. The project comprises partners from the social and natural sciences, planning, and water engineering. Furthermore, the project was intended to be *integrated*, that is not only to follow distinct work packages in parallel but to integrate them. Also, the project had a specific focus on the *development of methods and tools*. Although it was a research project, its aims were not only to develop scientific products such as transferable methods, models and peer-reviewed papers. But in addition, it deliberately included local stakeholders with the objective of having an impact on the real world in Lima, mainly by supporting the development of strategies for stakeholders and decision makers such as local water authorities. The project was *transdisciplinary*: It included partners from research and practice, amongst which stakeholders with diverging perspectives; and dealt with scientific requirements as well as real world expectations. Due to the fact that this was a German-Peruvian collaboration, the project was *intercultural.* Three project languages were used in parallel: Spanish, English and German. The project was not carried out in one place only, rather the work was distributed over several locations. The central venues were Lima in Peru as well as Stuttgart, Magdeburg, Suderburg, and Leipzig in Germany. The communication between these places was supported by regular project meetings in Germany and in Peru, virtual meetings, and email communications.

5.3.2.2 The bigger picture: a very rough sketch

The LiWa project itself, especially due to its transdisciplinary and applied nature, was embedded in the environmental, socio-political, institutional and cultural contexts of the water sector in Lima, Peru. In its nature as a German research project, it was primarily embedded in the context of German research culture and programs.

The water sector in Lima, Peru, is characterized by specific environmental as well as socio-technical settings: “The capital of Peru, Lima, with a fast growing population exceeding 8 million […] has to

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[170] Work packages as stated by the website of the project:
- Work package 1: Compilation of information
- Work package 2: Integrated scenario development
- Work package 3: Climate and water-balance modeling
- Work package 4: Macro-modeling and simulation system
- Work package 5: Participation and governance approach
- Work package 6: Education and capacity building
- Work package 7: Economic evaluation of water pricing options
- Work package 8: Project coordination
- Work package 9: Integrated urban planning strategies and planning tools

[171] URL:http://www.lima-water.de

draw a major part of its water supply from the River Rímac. Due to very dry conditions […] and large seasonal variations of river flow, also groundwater is being used as a source of water supply."[172]

The catchment areas of the rivers Rímac, Chilllón and Lurin in the Andean mountains are affected by climate change in the form of changes in temperature and precipitation patterns as well as of melting of glaciers. Thus, it is highly uncertain, if the future rivers' runoff will be sufficient to meet the needs of the growing city. The technical infrastructure is marked by coverage rates to the drinking water and waste water net of ca. 80% of the population, low waste water treatment and reuse rates as well as high network losses.[173]

A multitude of different institutions and actors is concerned with the water sector in Lima. For example, providing drinking water to the growing population of the city of Lima is the task of the water company SEDAPAL, operated by the Peruvian state (national level). Other national authorities are managing the catchment areas (ANA); again others are approving the water prices (SUNASS). Furthermore, several national ministries and the regional and the local administrations of the City of Lima (the municipality of Lima and its 43 district administrations) are involved. Some of these institutions have been created only recently and constitute new and emerging actors in the field.[174] Furthermore, several NGOs have been active in the water sector, some of them for decades. They are concerned about, among other things, the water situation of the poor, who are not connected to the water supply network but who are supplied by water trucks and pay "a multiple of the regular tariff to water vendors";[175] and with the water usage cultures of consumers. Historically, trust and cooperation between these different actors and institutions are rather limited**.**[176]

The LiWa project is also embedded in the context of German research culture, funding and programs. In 2004, the BMBF announced the funding program, Research for Sustainable Development of the Megacities of Tomorrow.[177] Within this programme, the LiWa project was funded for a two year pre-

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172 Source: URL: http://www.lima-water.de/en/lima.html?Menu=3.

173 Source URL: http://www.lima-water.de/en/lima.html?Menu=3.

174 Such as the Peruvian national water authority (ANA) in 2009 or the Peruvian Ministry of the Environment (MINAM) in 2008 (cf. DOC: ZB_IWS_ZIRIUS 2009: p.11).

175 URL: http://www.lima-water.de/documents/liwaflyer_pp4_en.pdf

176 Since the 1930s, Peru has known several military dictatorships—interrupted by some phases of more democratic regimes. From the 1980s into the 1990s internal conflict and guerrilla war created very difficult economic conditions in the country, with the Maoist movement Sendero Luminoso, the leftist guerilla Movimiento Revolucionario Tupac Amaru and the military as main actors. The internal conflict created a climate of terror and resulted in around 70,000 deaths. From the mid 1990s on, with the consecutive presidencies of Fujimori, Toledeo, the second term of Alan Garcia, and now Ollanta Humala, the political and economic situation has stabilized and the latter now performs quite well, mainly due to mining activities and agricultural production. For more information on the History of Peru, see e. g. Ploetz 1993; for the current economic and political situation, see Redaktion Fischer (2013).

177 In German: „Nachhaltige Stadtentwicklung: Forschung für die Megastädte von morgen" For more information on the future megacities program, see the website of the program:
URL: http://future-megacities.org/index.php?id=1&L=1.

phase and later, a five-year main funding period was approved, as one of 10 and later 9 such projects to take place between 2008 and 2013. The funding agency expected the project to provide both research products as well as real-world impacts.

5.3.2 Definition and justification

The exploratory case study Lima Water was closely linked to the megacity project LiWa, but it focuses on one specific aspect of the project only. It focuses on the use of CIB in combination with the modeling and simulation of natural and technological systems to support the construction of integrated scenarios on the future water supply of Lima, in short labeled Lima's water futures 2040. The application of this specific form of the combined CIB&S methodology by an interdisciplinary team is the phenomenon.

The Lima Water case is a relevant case, because it represents the usage of CIB through an interdisciplinary research team in combination with numerical modeling and simulation to construct socio-environmental scenarios. In the Lima Water case, all phases of the (ideal type) CIB&S process are covered. In a fairly participatory approach, qualitative scenarios are constructed by a Peruvian scenario group using the CIB method. These scenarios are translated and used for scenario calculation and evaluation through the water system simulator developed in the project, the so-called LiWatool. The process leads to integrated qualitative-quantitative scenarios.

The case study started with my introduction to the project in January 2010. Data collection was completed in March 2013. The runtime of the case study was thus shorter than the runtime of the overall LiWa project.

5.3.3 Access and roles

I had access to the Lima Water case, as a member of the research team, from January 2010 to March 2013.[178] From the beginning on, the project coordinators knew about my research interests and introduced me to the other project partners. They provided me access to meetings, documents and to those emails that were related to the scenario construction process. During the case study runtime, I attended all major project meetings of German partners and all joint meetings of German and Peruvian partners. Furthermore, I had the opportunity to do two field trips to Lima—three weeks in October 2011 and five weeks in March/April 2012.[179] Thus, all German and Peruvian project partners, especially the modelers and all the members of the scenario group and I got to know each other. I openly communicated my research interests during short presentations, each time I was first intro-

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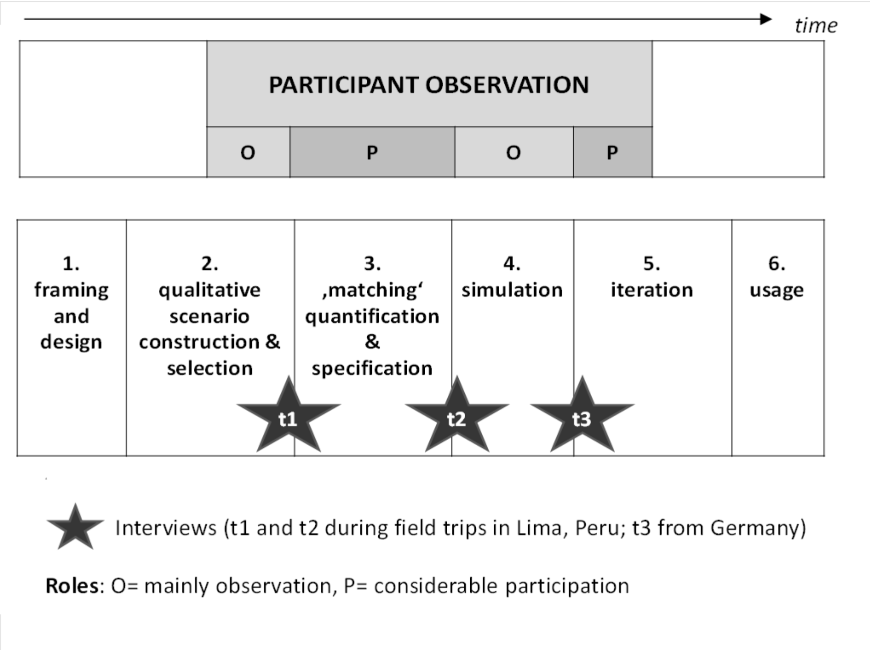
178 I left the LiWa project and terminated the data collection due to maternal leave.

179 These field trips were made possible through funding by the DFG graduate school "Simulation Technology, SimTech" at the University of Stuttgart.

duced to a group. Consent to be part of my case study was collected from all relevant participants during the interviews. During both field trips, I attended large public events organized by the LiWa project (so-called Round Tables), during which the CIB based scenarios were discussed with a larger public of external experts from the water sector in Lima. In October 2011, I conducted three training workshops on the CIB software, ScenarioWizard*,* for the benefit of the scenario group members and project partners in Lima, too.

Figure 16: My access to and impact on the combined scenario construction process (Lima Water)



As in the UBA case, I was in a double role: My first role was that of a project team member and more precisely of a CIB scenario expert. As such, I was actively involved mainly in the matching between CIB and LiWatool (phase 3) [180] and in the integration of scenario products at the end of the process (phase 5).[181] During both of these phases, I was considered the, so to say, combination person, meaning the mediator being positioned between the qualitative scenario group in Lima and the modelers in Germany and I had considerable impact on parts of the process, see Figure 16.[182] But, the specific form of combination, the methodology and the success of the CIB&S process strongly depended on

[180] At times, I took on the role of a facilitator of this process (see e. g. FN June_August 2011, FN March_Mai 2011, FN November_December 2011 as well as FN January 2012, FN FN WS tariffs II 20120606).
- Communicated intensely with the modelers on the aims and approach of the combined method and the need for quantifications.
- Preparing and sending around templates to collect information on indicators and time series.
- Initiating workshops on the quantification of specific issues such as on tariffs or on the issue of climate change and on green topics, bringing together the modelers, the scenario team and the issue-experts from within the project.

[181] I initiated and at times coordinated the preparation of a combined scenario brochure, publishing combined narrative and numerical aspects of the scenarios in an integrated way (Kosow, Leon, Schütze 2013).

[182] Therefore, at times I was also perceived as responsible for all other ZIRN tasks (storylines, round tables, e. g.).

the interest and contributions of the project partners, not by any means on my work alone. At the same time I was in the role of a method researcher doing her PhD, taking the perspective of the participant observer, archivist and interviewer.

5.3.4 Specifying the research questions

The specific research questions to the Lima Water case are the following:

(How) does the use of CIB within the specific combined scenario methodology of the Lima Water case support its interdisciplinary research group to construct integrated exploratory scenarios of Lima's water futures 2040?

1. In what *form is* CIB combined in the Lima Water case with the numerical water infrastructure simulation model LiWatool to support the construction of integrated (qualitative-quantitative) scenarios of Lima's water futures 2040? *(form of CIB&S)*
2. *What effects* does the use of CIB within the specific combined scenario methodology of the Lima Water case have on scenario *traceability* and scenario *consistency*? What are further (unintended) effects? (*outcomes*)
3. *How* are outcomes of the use of CIB *influenced* by other characteristics of the specific scenario *methodology* and by the specific *form* in which CIB is combined with the numerical simulation model LiWatool in the Lima Water case? (*factors*)

5.4 Data collection

In this section, I document the process and techniques of data collection. First, I make some general remarks on how this study has dealt with the issue of selectivity during data collection (5.4.1.). Then, I explain and document why, how and what type of empirical data was collected in this study through process documents (5.4.2), participant observation (5.4.3) and semi-structured interviews with process participants (5.4.4). Finally, I give an overview of how the different sources of evidence are jointly used to shed light on the different aspects of the phenomena (5.4.5).

In both individual case studies, overall the same data collection techniques have been applied. Data collection was individually prepared for each case in the form of a case study *protocol* (Yin 2009: 79). Details are documented within these (cf. Supplements A and B). A short overview of evidence collected in both cases is provided within this chapter. More details on the database, including a list of labels, under which evidence is referred to, is given in Annex G (case UBA) and Annex H (case Lima Water).

5.4.1 Selectivity issues and the overall criterion of relevance

The data collection for this study was confronted with challenges of *selectivity* that are typical of qualitative (case) studies. Miles/ Huberman (1994: 55 ff.) distinguish between two types of selectivity in data collection: *Endemic* (non-intentional) selectivity, since every perspective is selective, informants and observers are selective; and *intentional* selectivity, occurring through the focus on the issue under study. First, as described by Miles and Huberman (ibid), there was the need to balance between "data overload and sketchiness." In the Lima Water case, with a duration of more than three years, the amount of data was immense, especially when considering the data analysis, during which "[a]ll of this information piles up geometrically"(Miles/ Huberman 1994: 55). Thus it seemed highly advisable to me to avoid data overload. On the contrary, the UBA case had a short runtime and, due to limited access, rather risked sketchiness.

According to Miles and Huberman, "[c]onceptual frameworks and research questions are the best defense against overload" (Miles/ Huberman 1994: 55). But, as the authors also point out (e. g. ibid 35), there is a need to find an appropriate balance between *conceptual focus* (deductive approach) and *openness* to the field (inductive approach) (Miles/ Huberman 1994: 56): "The challenge is to be explicitly mindful of the purposes of your study and of the conceptual lenses you are training on it—while allowing yourself to be open to and reeducated by things you didn't know about or expect to find."

Table 11: Criterion of relevance: Does this piece of evidence teach me anything about…?

See definitions in chapter 4.

Independent categories	Dependent categories
• The design and use of *CIB* • The (social, technical or data related) *character* of the combined methodology, its process and scenario products • The *form* of combination of CIB with numerical modeling	• Scenario *traceability* • Scenario *consistency* • *Other effects* of CIB

To respond to both challenges, I have developed an overall criterion of relevance, guided by my conceptual framework and research questions: Every piece of evidence, independent of its source (process document, interview passage, observed phenomenon), is relevant for this study only if it allows me to learn something about the central concepts of my case, that is at least about one of the dimensions developed within the conceptual framework, see Table 11. This criterion has strongly focused the data collection. Necessary openness was ensured by the rather open type of operationalization (e. g. with regard to the social level of the methodology) and with regard to effects of CIB through the category of *other effects*. In the following sections, I detail how data was collected from different sources of evidence.

5.4.2 Central process documents

In both cases, material that is documenting the scenario processes and the (interim and final) scenario products was collected. Process documents, comprising project proposals, (interim) reports, presentations, agendas, official protocols of meetings, CIB matrices, data sheets and scenario texts, have a double function: First, they provide me with the official presentation of both context projects; and second, they provide me with evidence on those events and project activities that I could not personally attend, as they were taking place in a different place or before or after the case study. Yin (2009: 102) emphasizes that process documents have the advantage that they are non-reactive as they are not influenced by the process of collection itself.[183]

During both case studies, process documents and material were collected and critically checked against the overall criterion of relevance. I was not striving for completeness, but rather for focus on the central documents that provide sufficient documentation to allow descriptions of the planned and documented scenario process and methodology; and to allow the later consistency analysis of the different forms of (interim) scenario products.

For each process document (DOC), a summary sheet (cf. Yin 2002, Miles/ Huberman 1994) was filled in (see Supplements A and B). Original documents were digitally stored. Finally, in the UBA case, n= 11, in the Lima Water case n= 45 process documents were included in the analysis. For the distribution over time in the Lima Water case, see Table 14.

Emails are not considered process documents, but understood as written project communication that was filtered through participant observation, which is the topic of the following section.

5.4.3 Participant observation

During both case studies, further evidence was collected through participant observation. *Participant observation* (cf. e. g. Atteslander 2000) is one of the classical methods practiced in “anthropological studies of different cultures of social groups“ (Yin 2009: 112), but is increasingly applied in ethnographic research on our own culture(s), too (cf. e. g. Gerold 2005). When a phenomenon is embedded in social situations and difficult to access from the outside, with participant observation, it can be observed from an insider perspective (cf. Atteslander 2000). Furthermore, participant observation makes it possible to influence a case study in the role of an active investigator (cf. Yin 2009: 112). Authors agree that deeper involvement can lead to different forms of bias (see Yin with an evaluation from the perspective of case study research 2009: 112). Still, I chose this approach since this form of

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183 In addition, some of these documents officially document my influence onto the scenario process in the UBA and Lima Water case (such as the proposal in the UBA case or the final scenario brochure in the Lima Water case).

data collection was the only way not only to *access* the internal processes of the scenario methodology but also to *realize* empirical cases of CIB&S for this study.

In both case studies, I did *open* (in contrast to covered) participant observation, which also meant to openly communicate my two roles (team member and method researcher). In both cases, at times my involvement was strong, and I was an observing participant, at other moments, I was more of an almost non-participating observer. In the UBA case, participant observation during the scenario process was less important than in the Lima Water case. An issue raised by Yin (2009: 112) at times occurred in the Lima Water case: “The participant role may simply require too much attention relative to the observer role. Thus the participant observer may not have sufficient time to take notes or to raise questions about events from a different perspective, as a good observer might.”

At times during the Lima Water case I was deeply involved in supporting the scenario process. I was then not (only) observing natives in their culture, but, together with other actors, I was trying out a new methodology, writing emails, giving presentations, organizing workshops etc. Still, such phases alternated with others during which I regained my distance and found myself back in an observers’ position. The participant observation was *slightly* (in contrast to un- or fully) *structured* through the overall criterion of relevance and the pre-defined conceptual framework.

In both cases, I selectively chose my points of observation. In the UBA case, in which main parts of the scenario process took place in Germany while I was in the USA (cf. 5.2.3), I used all given occasions for direct observation. For those phases during which I was not present, I relied more strongly on process documents and reports by other participants. In the Lima Water case, due to the multi-setting character of the case, I was able to observe the project activities mainly through email communication (the project’s main means of communication), as well as during selected events, when actors met virtually for skype conferences or personally during (project) meetings or workshops. Two field trips to Lima allowed me to observe the Peruvian side (cf. 5.3.3).

Again, participant observation was not intended to provide completeness, but to cover the critical moments of the scenario process, as far as possible. Participant observation was mainly directed at collecting evidence about the *effective* (in contrast to the planned and documented) character of the methodologies and the forms of the combination that were realized in both cases. In addition, participant observation was a source of evidence with regard to issues of *consistency*, *traceability* and *other effects* of CIB.

I immediately wrote down my observations in the form of open note taking during observed situations. During the two field trips to Lima, entire diaries were filled. These notes then have been structured and condensed into field notes, more strongly focusing onto those issues that were considered relevant (overall criterion). Finally, every field note (FN) was summarized by a summary sheet, too (see Supplements A and B).

As I pointed out above, emails were the main means of project communication, especially in the Lima Water case. This was due to the fact that actors were in different locations and some of them preferred email. Different time-zones and weak sound quality meant that skype was not often used. This was challenging: First, the sheer number of emails, especially in the Lima Water case, did not allow to use them verbatim as original process documents—which in addition would have caused difficulties for anonymity and consent. The solution I found during the course of the case was to prepare not only event-related field notes, but additionally to write down monthly field notes. These summarized my hand written notes and the emails I had access to (up to 20 per day during intense phases). These were then structured by issue—instead of being chronological. In consequence, the interpretive character of the monthly field notes is higher than that of the event notes.

Finally, in the UBA case n= 4, in the Lima Water case n= 22 pieces of field notes were included in the analysis. For the distribution over time in the Lima Water case, see Table 14 (in section 5.4.5).

5.4.4 Semi-structured interviews with process participants

In addition to the process documents and my observation and experience, I collected evidence through interviews with process participants to include their perspectives into the study.

5.4.4.1 Form of qualitative interviews

In both cases, I conducted *qualitative interviews with process participants*, in case study research sometimes also called “informants” (Yin 2009).[184] A few of the process participants (modelers, scenario group members, CIB scenario experts) were themselves experts for (combined) scenario methodologies and were able to provide “context knowledge” (Meuser/ Nagel 2009: 468), from experiences beyond the case study. All participants had experienced the use of CIB in combination with numerical modeling, so they had acquired internal “operational knowledge” (ibid.). They had insider insights on parts of the process that I had had no access to, and their own perception and experience of the phenomena. In that sense, the participants were experts. With regard to other aspects they were more like *users* of a methodology. Still, they were not passive consumers but actively involved into co-constructing the methodology and thus finally, their case. Therefore, talking to

[184] Qualitative interviews are one of the central approaches of case study research and of qualitative social research in general. They are used to give a voice to the subjects of research (cf. Mayring 2003: 66), i.e. to learn about actors’ perceptions, attitudes and assessments. There is a large variety of different qualitative interview types and techniques (for an overview and characterization see, e. g., Lamnek 2005). Authors often distinguish between open, semi-structured and structured approaches (e. g. Di Cicco-Blum/Crabtree 2006). One variety or the qualitative interview is the so-called “expert-interview” (see for an overview Bogner/ Littig/ Menz 2005), during which interviewee and interviewer ideally have an expert conversation among equals.

them was an important source of information on perceptions of the process, on assessments of outcomes as well as on interpretation of effects by different actor groups.[185]

The interviews were *problem-centered* (cf. e. g. Witzel 2000), that is their focus was on the use of CIB within the specific integrated scenario methodology of the respective case and its effects. Their aim was to encourage the different participants to narrate their perspective as well as to cross check their understanding of the problem and assessments of the case with mine.

The interviews were *semi-structured*, meaning "organized around a set of predetermined open-ended questions, with other questions emerging from the dialogue between interviewer and interviewee." (Di Cicco-Blum/ Crabtree 2006: 315). I started with very open questions inciting interview partners to narrate, how they had perceived the scenario process, that is telling their personal story about the process. I ended with questions directed at the assessment of the CIB method and its potential effects, in case participants had not raised specific issues, or raised them in only a cursory way. The interviews left room for the interviewees to discuss other issues. This was important for the openness of the data collection and to balance the artificial character of the situation. The semi-structured, that is in part standardized, character of the interviews was chosen to allow comparisons of statements across interviews, actor groups and cases.

5.4.4.2 Sampling

With regard to the *sampling* of interviewees, I followed two strategies: First, I focused on including representatives of all the central groups of case participants—internal or 'producer users': CIB scenario experts, scenario group members and modelers. Second, I tried to include the most relevant informants: the actors, who had the most important roles and responsibilities within the process, those who had experienced most phases of the process and also had some overview, and had done so in the most continuous way. The samples of interviewees of both cases do correspond quite well to these aims.

Table 12 gives an overview of the sampling of the UBA case. Overall, n= 8 interviews were conducted. Although some of the members of the UBA scenario group were trained as modelers themselves or anticipated the modelers' perspective, the actual modelers, did not participate as a group sui-generis during this case as they are generally are not working directly at UBA (see also chapter 6).

[185] Further socio-demographic and or biographic issues were not considered relevant.

Table 12: Sampling of interview partners, type and timing of interviews (UBA)

F= face to face, T= telephone; natural sciences include engineering and mathematics, social sciences include economics. All interviews were conducted in German.

Case UBA						
Label	**Role**	**Institution**	**Discipline**	**Type**	**Timing**	**Sum interviews per group**
Expert V	CIB scenario experts	ZIRIUS	Natural sciences	F	Ex post, July 2011	n= 2
Expert W			Social sciences	F	Ex post, July 2011	
Expert A	Scenario group	UBA	Natural sciences	T	Ex post, March 2011	n= 6
Expert B			Social sciences	T	Ex post, March 2011	
Expert C			Natural sciences	T	Ex post, March 2011	
Expert D			Social sciences	T	Ex post, March 2011	
Expert E			Social sciences	T	Ex post, March 2011	
Expert F			Natural sciences	T	Ex post, March 2011	

Sum interviews n= 8

A specific challenge consisted in identifying those actors, who had experienced most of the process steps. This goal was achieved, and the informants that were best in this sense were interviewed. For more detail on the participation of the different actors during the different phases of the process see Annex I. Disciplinary backgrounds, roughly grouped into natural science and engineering vs. social sciences, and gender were fully equally distributed among CIB scenario experts as well as among scenario group members.

Table 13 gives an overview of the sampling of interviewees in the Lima Water case. In three waves of interviews, overall n= 25 interviews with in total 16 different persons were conducted. In this case, a challenging aspect of sampling was to include the representatives of the groups of actors, who were assumed to have the most relevant insight into the specific process phases that were at stake during the respective interview wave. This was successful as well, overall. During the first wave of interviews (t1), the process was still within the scenario construction with CIB, during which modelers did not actively participate. Modelers were therefore not included in this wave. During the second wave (t2) they were asked about their perception of the foregoing phases, too. In addition to the internal actor groups, in the Lima Water case, two groups of recipient users were included in the interviews. First, two external modelers were interviewed in order to strengthen the evidence with regard to the perceptions of modelers. Both had used the qualitative CIB based scenarios to do simulations with a numerical water balance model in the context of their study thesis. Second, three additional interviews with stakeholders from the target user organizations in Lima were conducted in order to get at least an idea of external users' perceptions of the process and of the resulting scenarios. These interviewees had learned about the scenarios during semi-public project events in Lima.

Table 13: Sampling of interview partners, type and timing of interviews (Lima Water)

DE = Germany, P = Peru, F= face to face, S= Skype; interviews in German (Ger), English (Engl) and Spanish (Esp).

Case Lima Water										
Label	**Role**		**Insititution**	**Discipline**	**Timing and type**			**Language**	**Actor group**	**Sum actors**
					t1	**t2**	**t3**			
Expert L	CIB scenario experts		Research (DE)	Engineering, social sciences	S	S	S	Ger	CIB scenario experts	n= 2
Expert M					S	F		Ger		
Expert O	Modelers			Engineering, mathematics		F	S	Ger	Internal modeler	n= 2
Expert Q						S		Ger		
Extern 4						F		Ger	*External modelers*	n= 2
Extern 5						S		Ger		
Expert N	Local experts/stakeholders	Scenario group	NGOs (P)	Architecture, social sciences, engineering	F		S	Engl	Scenario group	n= 7
Expert K					F			Esp		
Expert P						F		Esp		
Expert J					F			Esp		
Expert G					F	F		Esp		
Expert H			Water company (P)	Engineering	F	F		Esp		
Expert I					F	F	S	Esp		
Extern 1		Ex-ternal				F		Esp	*External stake-holders*	n= 3
Extern 2			Urban planning unit (P)	*Architecture*		F		Esp		
Extern 3						F		Esp		

Period	Sum
t1 September-November 2011 phases: (framing), construction of CIB scenarios, loop I	Sum n= 8
t2 March-June 2012 phases: matching, storyline writing, loop II (and simulation)	Sum n= 13
t3 March 2013 phases: matching, simulation, loop III and IV, integration and iteration, (usage)	Sum n= 4

Sum interviews n= 25

Sum interviewees n= 16

Gender was quite equally distributed among all actor groups. Each group comprised at least one person of each gender, in total eight men and eight women were interviewed. Actors came from a multitude of disciplines, with a slight dominance of (water) engineering and architecture compared with social sciences

5.4.4.3 Guidelines

In both cases, the interviews are the main source of evidence with regard to the subjective perception of scenario traceability, of other effects of CIB and of the methodology by the different actor groups. In addition, they are an important source to learn about the scenario process and the methodology as they were *perceived* by the different actor groups. The interviews were framed as research on CIB to learn about the participants' views on how to enhance the method. They were supported by guidelines that were individually adapted for each interview in function of the case and of the user group (distinguishing between scenario group, modelers, CIB scenario experts and external actors). For the Lima Water interviews, guidelines were also adapted with regard to the time waves, covering different phases of the process (see Table 13 above). As a result, interviews were specifically tailored to those phases of the combined methodology that the participants had (already) experienced.[186]

Still, the different interview guidelines were all structured using the following blocks of questions: Introduction (I), a rather open narration phase on scenario process and results (II and III), more focused and standardized questions mainly asking for specific assessments (IV- VI), and a final block opening the scope of the conversation again. Note that the order of questions, especially III- VI, was handled flexibly according to the flow of the conversation.

I. Introduction and opener

As an introduction, I explained the aim of the interview, guaranteed anonymity, asked for consent to record, and emphasized that I am interested in personal, subjective perspectives and assessments. Then I guided the interviewees to the specific issue of the interview, by asking, e. g.: “What are your experiences with environmental scenarios?” (cf. UBA, guidelines scenario group) or “The scenarios of the LiWa project “Lima 2040” have been constructed by you and the others from the scenario group. You have been using a specific method, the cross-impact balance analysis (CIB). What steps of the process did you participate in?” (Lima Water, guidelines scenario group t1).

II. Narrating the process, covering the different phases

This section was especially important for the purpose of gaining the participants’ insider perception of the scenario process. I asked the interviewees to report about their experiences during the scenario process, e. g.: “Could you tell me about your experiences in the last weeks and months with the scenario approach that we use in the LiWa project, i.e. about your personal experiences with the combination of the CIB scenario analysis with LiWatool simulation?” (Lima Water, guidelines scenario group t3).

First, I tended to ask about the overall process; but then, especially in the Lima Water case, I reconstructed the different process phases, activities and events together with the interviewees. Together with the interviewees, I went through each phase and activity by asking: “What worked well, what did not work well? *(Where did you experience problems or difficulties? Why did they occur and what could have been done better?)”* (Lima Water, guidelines scenario group t2).

III. Talking about results

I then focused on the scenarios resulting of the process by asking, for example: “What are the most important results up to now, and how do you see them?” (UBA, guidelines scenario group). This was intended to clarify what was perceived as a result and to get first assessments. In case actors did not

186 Overall, interviews were adapted in function of the interviewees’ method expertise and on his/her inclusion into specific phases. But I also asked actors about phases they had not actively experienced themselves to learn about the ’internal-external’s’ view.

come up with the issues themselves, I asked (in all interviews in some form): "What is your impression of the scenarios [CIB scenarios, input data sets, LiWatool, the integrated brochure etc.]?" and also "Would you use these in other contexts or give them to colleagues?"

After this rather open and narrative phase, I explored three dimensions in a more structured and directed way, especially asking about the participants' assessments. These questions were asked only if participants had not yet mentioned the issues or if I felt it necessary to ask, whether I had correctly understood the assessment they had given.

IV. Further exploring usability issues[187]

In order to learn how participants assessed the usability of the scenario approach, I asked about effort, effectiveness and subjective content (in both cases, all actor groups):

- "How costly and time consuming has the scenario process been until now? (*Please explain*)"
- "Was it worth the effort?"
- "How did you feel about the methods that were used? (Did you tend to like them or tend to dislike them)? "
- "Would you apply the CIB method yourself or recommend it to others who want to construct scenarios?"

V. Further exploring traceability issues

In order to learn how participants assessed scenario traceability (in the Lima Water case, of different forms of scenarios), I asked the following types of questions (guidelines Lima Water, all types of actors, t2 and t3):

- "How difficult is it to understand the CIB method [LiWatool/ the combined approach/ Matching etc..] and to understand how it works? *(comprehensibility)*
- "Are the scenario process and the decisions made throughout it easy to follow? And [would they be/were they] easy for somebody who did not work with you [e. g. in the scenario group]? *(traceability of procedures)*
- "In the scenario process, we started with CIB: You and the scenario group built the CIB matrix. How clear is it for you what process steps were used to get from the CIB matrix to the combined scenario brochure (containing storylines and simulations) and what has remained unclear or not entirely transparent? " *(traceability of procedures)*
- "If you think about the storylines [raw CIB scenarios, input data sets, integrated scenarios], do you find it easy to understand what ideas they contain about the water future of Lima? ➔ And what ideas they contain concerning how different future developments will be linked to each other? ➔ (For whom? For actors of the scenario group? Within the Lima Water project? Why or why not)?" (*assumptions on future developments and interrelations)*

[187] Initially, usability was one of the focal issues of the conceptual framework. During the course of the study, it lost its centrality. Nevertheless, the usability-related answers made it possible to learn about important aspects with regard to the social, technical and cognitive organization of the process, and about the perception of effects beyond scenario traceability and consistency.

VI. Further exploring consistency issues

Consistency issues were not the central focus during the interviews. Nevertheless, I asked the following question: "Do the combined scenarios (storylines and simulations) match your ideas on the possible water futures of Lima? Do you recognize the work that you and the scenario group have put into the CIB matrix?" *(systematic vs. intuitive consistency criterion)* (Lima Water, guidelines experts t3).

VII. Overall assessment and further comments

For an overall final assessment, I asked the following question (Lima Water, modelers and CIB-scenario experts, t3): "Please imagine you are a consultant. The mayor of Cairo contacts you because he wants to construct scenarios about the future of his city. He asks you whether he should use the same combined scenario method as in the LiWa project, and *what the strengths and weaknesses* of the combination of CIB & LiWatool are?"

Then, to close the interview I opened up the conversation again, to allow room for further thoughts, comments and feelings: "How do you feel about the scenarios and about the scenario process (at the moment)? And "Do you have further comments, suggestions, anything you would like to let me know?" In the UBA case and in the first interview with each actor in the Lima Water case, I also asked the participants to supply their professional backgrounds and (academic) disciplines. Finally, I thanked the interview partners.

5.4.4.4 Implementation

I conducted the interviews in the form of face-to-face interviews if feasible, otherwise by telephone or skype. For the timing, types and languages of interviews, please consider Table 12 and Table 13 again.

In the UBA case, ex-post interviews were conducted with the scenario experts in March 2011, when the final report had been published, and in July 2011 with the CIB scenario experts. In the Lima Water case, due to its long duration, interviews were carried out in parallel to the ongoing process. I decided to conduct the interviews with the scenario group personally, to allow the interview situation to establish and strengthen the contact and mutual trust between the Peruvian stakeholders and me. This decision influenced the timing, as field trips to Lima needed to be organized. Initially, two waves of interviews had been foreseen, linked to the field trips to Lima. Both field trips in turn had been planned around official project events in Lima, which had been planned in anticipation of reaching specific milestones in the scenario process. But, as the process was lagging behind initial time plans, the first wave (t1) could take into account only the framing and the qualitative scenario construction with CIB. During the second wave (t2), the first simulations had only just been generated and the matching was still in progress. Therefore, a very slim third interview wave (t3) was decided upon at the very end of the official runtime of this case study, when the entire CIB&S process had been accomplished.

The interviews in both cases took about 60 minutes on average. They were audio recorded,[188] and I filled in a summary sheet directly after each interview (see Supplement A and B).

5.4.5 Comparing data of both cases and using multiple sources of evidence

Table 14 gives an overview of the data collected in both case studies from all three sources of evidence, for more detail see Annex G and Annex H. The differences between the cases reflect the different durations of the cases (ca. 7 vs. 39 months) as well as my different access and roles. In the UBA case, process documents had more weight when it came to learning about the process, the methodology and the form of combination, since direct participant observation had been more limited. In the Lima Water case, due to my occasionally more active involvement, participant information was a more important source of information.

Table 14: Overview of evidence from three sources (UBA and Lima Water)

	UBA	Lima Water					*Sum across cases*
	2010/2011	2010	2011	2012	2013	Overall	
Central process documents (DOC)	n= 11	(2008-2010) n= 11	n= 9	n= 14	n= 11	n= 45	n= 56
Field notes (FN)	n= 4	n= 3	n= 7	n= 9	n= 3	n= 22	n= 26
Interviews	n= 8	/	t1 n= 8	t2 n= 13	t3 n= 4	n= 25	n= 33

The interview phase of the Lima water case started, when the UBA data collection had been already completed. Thus, there have been learning effects with regard to the interviews (e. g. the guidelines and the conversation techniques) but also with regard to the selectivity with documents and the technique of observation. There have been learning effects in terms of content and concepts, which were further sharpening and refining the focus of this study; further learning effects occured during the long runtime of the Lima Water case.

Table 15 shows the role the three sources of evidence play with regard to the different conceptual elements of this study (across cases). Furthermore, it shows that for each conceptual dimension, information from at least two sources of evidence was collected. With regard to the scenario processes and their methodologies and with regard to the form of combination (i.e. the independent categories), participant observation was the main source of information on the *effective* realization. Process documents tended to provide more information about how the process had been *planned*

[188] During one of the Interviews of the last wave in the Lima Water case the skype recording became corrupted. I noticed the problem immediately after the interview, and based on my detailed handwritten notes, which I always take during interviews, I reconstructed the interview and sent the summary for validation to the expert (see the interview with the Lima Water expert I t3).

and *documented* and interviews provided me with a more subjective perspective on how the process and its methodology had been *experienced* by different actor groups.

Table 15: Overview of sources of evidence per conceptual issue (UBA and Lima Water)

Legend: **X:** main source of evidence, (X): complementary source of evidence

	Source of evidence *Issues*	**Process documents**	**Participant observation**	**Interviews with process participants**
Independent categories	**Process and methodology** (CIB, further methods, actors, data)	(X) (as intended and documented)	**X** (as effective)	(X) (as experienced)
	Form of combination of CIB and num. model	(X)	**X**	
Dependent categories	**Traceability**		(X)	**X**
	Consistency	**X**	(X)	
	Other effects		(X)	**X**

With regard to *traceability* issues and other effects of the methodology, interviews with process participants were the central source of information. Process documents, and specifically the different forms of (interim) scenario products provided the basis for the later *consistency* analysis, experience from observation helped to ascribe traceability and consistency levels as well as other effects to the methodology.

This strategy is a soft form of data triangulation, with the purpose to support or to question findings with the help of more than one source of evidence, and to balance the respective strengths and weaknesses of each source of evidence (cf. Yin 2009: 41).

5.5 Data analysis and interpretation strategies

"The analysis of case study evidence is one of the least developed and most difficult aspects of doing case studies" (Yin 2002: 127).[189] In this section, I document how this task was fulfilled in this study. First, data needed to undergo some preparation (5.6.1). Second, I coded the databases of both cases thematically (5.6.2). Third, each case was individually described, analyzed and interpreted, supported by qualitative data and content analysis. I used key informant review to refine the case reports (5.6.3). Fourth, I compared and interpreted my findings across cases and formulated general insights, which were synthesized and validated during an expert workshop (5.6.4).

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189 Yin himself proposes four general strategies (2009: 131 ff.), this study follows three of them, namely (1) "relying on theoretical propositions," i.e. the expectations developed in chapter 4, (2); "developing a case description," especially concerning the independent and dependent variables; and (3) "examining rival explanations," especially with regard to the interpretation of whether and how effects are caused by CIB and or its interplay with other elements of the methodology. Yin's fourth strategy, "using both qualitative and quantitative data," does not apply to this study. Still, these strategies are too general to technically guide the analysis. Further, more technical advice can be foundin Tellis (1997) as well as in Miles and Huberman (1994), e. g.

5.5.1 Data preparation

First of all, interview audio files were *transcribed* word for word at full length (cf. Mayring 2003: 89 ff.). I decided to transfer conversational language into more easily readable written language, as this study was interested in the content of the interviews but not in the forms and linguistic details of statements.

Second, this study needed to deal with data in *different languages*. To do so, a *multilingual procedure* was chosen, following Lauf and Peter (2001): I had decided on English for the PhD project and report language. Evidence was collected in the native languages: The UBA case evidence is in German. The Lima Water case evidence is trilingual: parts are in German (e. g. interviews with German participants), parts are in English (e. g. my field notes that were composed in the project language), and parts are in Spanish (e. g. process documents and interviews with Peruvian partners) (cf. also table 3 above). I decided to keep the original evidence in these multiple languages. Summarizing evidence tables were produced in English and original quotations cited in the reporting chapters were translated into English, too.[190] This procedure was assessed adequate since the data analysis was concerned only with the content.

Third, it was decided that the cases were to be fully identified because they are publicly accessible research projects. But the anonymity of the individuals had been agreed upon with the interviewed actors to support openness and trust during the interview situation and to reduce political-correctness and social-desirability effects (cf. Yin 2009: 181 for different strategies to anonymize case studies). Therefore, data needed to be anonymized. Interview transcripts were anonymized by deleting the names. Still, the identities especially of the central actors of the cases are not protected through these transcripts. The same is true with regard to documents and field notes. Therefore, I have not included the database in the study supplements. With regard to the presentation of findings, I considered important that statements should be attributable to specific actor groups, but not to individuals.[191]

Fourth, the digitalized databases of both cases, each comprising process documents, field notes and interview transcripts, were transferred to the computer program MAXQDA. This qualitative analysis software was used to structure and organize the data of each case in the form of one MAXQDA project through coding.

[190] The statements in their original language are listed in Annex J (UBA) and in Annex K (Lima Water).

[191] For reasons of anonymity and uniformity in the presentation, all participants are spoken of in the masculine form. But please remember that gender was equally distributed within and among actor groups.

5.5.2 Thematic coding

To start the data analysis, the categories of the conceptual framework were used to *code* the collected data. “Codes are tags or labels for assessing units of meaning to the descriptive or inferential information compiled during a study.” (Miles/ Huberman 1994: 56). During coding, they “are attached to ‘chunks’ of varying size—words, phrases, sentences, or whole paragraphs” (Miles/ Huberman 1994: 56). Codes are organized in code-schemes, ordering individual codes under more general ones that in turn are comprised under the most generalized concepts of the study. There are different strategies to coding (cf. e. g. Miles/ Huberman 1994: 58 ff.) depending on the degree to which the codes are defined and structured a priori—if at all. In theoretical coding, codes are deduced from theory and predefined and structured before they are confronted with the empirical material. In thematic coding, codes are inductively constructed from or grounded by the empirical material. The third way of coding described by Miles and Huberman (ibid.) is “accounting scheme guided” coding, in which only the most general levels of concepts are predefined but categories are then inductively filled through the material.

In this study, the code scheme was initially pre-defined and pre-ordered by the concepts defined and, to a certain degree, operationalized in the conceptual framework (see chapter 4 and mainly: process phases; social, technical and cognitive characteristics of scenario methodologies; dimensions to describe forms of the combinations; scenario traceability; scenario consistency; further phenomena). This predefined approach was chosen to focus the data analysis, also to ensure a joint focus on both cases. Still, during the coding of both cases, codes schemes were considerably extended and refined through empirically found dimensions but also categories, especially with regard to other effects and with regard to the social, technical and cognitive characteristics of the methodologies. Through coding, the conceptual framework was pre-tested against the UBA and Lima Water case. The new empirically relevant definitions and categories were fed back into the conceptual framework that was adapted, especially concerning the social organization of scenario methodologies.

5.5.3 Within-case analysis and key informant review

Once the material of each case was coded, a qualitative *within-case analysis* was carried out. For each case, this resulted in a first-draft version of the case report, describing the process, assessing its outcomes, and interpreting the patterns in which CIB and other elements of the methodology had (co-)contributed to or hindered different effects (5.5.3.1). These draft reports were reviewed by key informants of each case and their comments used to refine analysis and reports (5.5.3.2).

5.5.3.1 Qualitative data and content analysis

Methods of qualitative data and content analysis were developed in various fields and against the background of different schools and paradigms of social sciences. Even if they are all based on the idea of analyzing empirical material with the help of categories, they range from very interpretative to almost quantitative approaches.[192]

In this study, the within-case analysis was guided and focused by the expectations that had been developed beforehand (see chapter 4). To confront each empirical case with these expectations required three steps: The description of its process and methodology, the assessment of scenario traceability, consistency and of other effects of CIB, and then the interpretation of patterns of effects. To realize these, several techniques needed to be applied and combined: The description of the process and the characterization of the form of combination of CIB with numerical modeling, the condensation of traceability assessments and the perception of other effects through different actor groups were carried out mainly by content summarizing techniques as described by Mayring (2003).[193] They were supported by detailed descriptive displays (according to Miles/ Huberman 1994), e. g., of the social, technical and cognitive character of activities over time (a sort of time series description, cf. Yin 2009: 144), to document the possible suspects that might have influenced scenario traceability, consistency and further phenomena. On a few selected occasions, additional qualitative cross-tables (cf. Miles/ Huberman 1994.) were used that were also requiring evaluative elements.

To establish the level of consistency of different forms of (interim and final) scenario products, a different approach was chosen. Especially in the Lima water case, for each form of scenarios (raw, storylines, input data sets, and integrated scenarios), the most important versions over time had to be selected and were then compared through content analysis considering structure and content of scenarios.

Finally, for interpretation, I traced outcomes back to either the use of CIB and/or other possible explanations, such as further social, technical or cognitive characteristics of the methodology. I discussed, whether the use of CIB, further rivals alone or their interplay did (best) explain the levels of scenario traceability and scenario consistency as well as further phenomena in each case. In the Lima Water case, I was able to follow the propagation of scenario traceability and consistency throughout the process. This was possible since, for both the independent and the dependent categories, I had structured the analysis in chronological phases with the corresponding (interim) products.[194] More detail can be found in the case reports in chapters 6 and 7.

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192 Kuckartz (2010: 72 ff.) distinguishes between three basic forms: content-wise structuring, evaluative and type-building forms (*inhaltlich strukturierende qualitative*, *evaluative qualitative*, *typenbildende Inhaltsanalyse*).

193 Mayring himself distinguishes three strategies of content analysis: Summary, explication, structuring (*Zusammenfassung, Explikation, Strukturierung*).

194 Building chronologies to trace events over time is a special form of time series analysis. For more information, see Yin (2009: 148).

5.5.3.2 Key informant review of draft reports

As recommend by Yin (2009: 182), drafts of the individual case reports have been critically discussed and validated by the respective key informants of each case. “Key informants are selected for their knowledge and role in a setting and their willingness and ability to serve as translators, teachers, mentors and or commentators for the researcher” (Di Cicco-Blum/ Crabtree 2006: 315). In the UBA case, the UBA project manager (at the same time member of the scenario group) and the CIB scenario expert with the primary responsibility were identified as key informants. In the Lima Water case these roles were taken over by the modeler responsible and by the scenario expert, who had organized and facilitated the scenario process with the scenario group in Lima. They commented in written form on the drafts of the respective case reports. This validation had the primary goal of ensuring that my case *descriptions* met the perception by the key actors in the cases.[195] But I also invited the actors to critically comment on my findings and interpretations.[196] The comments, additions and critique were then considered and used in particular to refine and to nuance the description of the respective process, its methodology and form of combination. They were also used to challenge my interpretations and to write more valid final versions of the case reports (chapters 6 and 7).

5.5.4 Cross-case synthesis and expert validation

I have compared the findings of the UBA and the Lima Water case across cases (5.5.4.1). Then, to generalize my findings, I have formulated general insights. These have been validated by experts (5.5.4.2).

5.5.4.1 Cross-case analysis and synthesis

The empirical study is based on two unique cases: individual and even idiosyncratic forms of the use of CIB within integrated scenario methodologies (cf. 5.1). Following Yin (2009: 15, 38), this study does not focus on achieving “statistical generalization” but rather “analytic generalization,” which is to say generalization on the level of conceptual considerations.

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195 Yin (2009: 182) stresses: “The informants and participants may still disagree with an investigator’s conclusions and interpretations, but the reviewers should not disagree over the actual facts of the case.”

196 The cover letters of the summary draft reports introduced the task in the following way:
“[…] You are one of the central actors of the case study UBA/ Lima Water and you have highly relevant insights into the method application and its potential effects during the UBA/ LiWa project. Therefore, I would like to ask you to help me gathering the best available knowledge:
Overall task: Please read critically through this report and please comment on, add to, contradict or doubt my findings. Feel free to comment wherever and however you like (using the WORD comment function or with pen on paper, e. g.).
1. *Please correct the case description and characterization* (Chapters 1-3). Within the text, there are questions directed to you (@name), either asking whether my descriptions are accurate or asking for further information. These questions are marked in light blue.
Please validate or contradict my findings (Chapters 4-6). Feel free to comment on, contradict, add to or question my results and interpretations based on your experience and perception of the case: All comments are very welcome! […].”

Miles and Huberman (1994: 174 ff.) give an overview of strategies for cross-case analysis, basically distinguishing between 'case vs. variable oriented strategies'. In this study, a combination of both was carried out. First, on a descriptive level, I compared the independent categories, looking for similarities and differences. For this purpose I used descriptive displays comparing the expressions of different aspects, such as the social, technical and cognitive organization of the two methodologies. The characteristics of each form of combinations and methodologies are sharpened through contrast with the other form. Furthermore, very few similarities in context and methodology beyond the use of CIB were identified that needed to be taken into consideration as potential rival explanations for similarities in outcomes.

Second, on a more analytical level, I compared the patterns of the effects of CIB and of other factors across cases. I compared with each other the outcomes of both case studies in terms of scenario traceability and scenario consistency as well as with regard to further phenomena. In addition, I contrasted findings from both cases with the initially formulated expectations. This allowed me to compare the *patterns* of factors (CIB and rivals, that is methodologies, combined forms etc.) explaining the levels of scenario traceability and consistency reached in each case.

Third, relying on argumentative interpretation (cf. Yin 2009: 160), I have formulated overall insights with the aim of synthesizing and generalizing, what I had found out about the effects of using CIB in different combine forms, along with the factors contributing to these effects.

5.5.4.2 Expert validation

To support my generalizing insights drawn from the cross-case analysis, another form of communicative validation (e. g. Mayring 2003: 112) was applied. To discuss my insights and their generalizability with the perspectives of other experts of the field, I organized an expert workshop. The group situation was chosen to allow several different perspectives to meet and to exchange ideas in a discursive way. I invited six CIB scenario experts and modelers, all of whom had themselves used CIB within combined scenario methodologies. [197] Five of them had been actively involved in one or even two of the case studies and these experts also comprised the key informants. Three of the experts had additional experiences from the more current use of CIB in combination with energy models within the ENERGY TRANS project.[198]

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[197] Due to the difficulties we had in finding a joint date agreeable to all participants, five of the experts participated during the workshop, and for one expert an additional individual meeting was arranged briefly afterwards.

[198] Please visit URL:http://www.energy-trans.de/english/index.php.

Prior to conducting the workshop, I sent around a five page document, summarizing six insights. These were discussed during a virtual expert workshop of three hours in July 2015.[199] The workshop started with a short introduction to this study, its cases and its conceptual framework; then insights were discussed.[200] Comments, additions, critique and nuances were first noted and, immediately after the workshop, summed up in the form of minutes (see supplement E). These comments provided me with the perspective of the practitioners and were used to refine and to better differentiate my overall insights and to further specify the analytical framework.

5.6 Quality of the empirical study

In this section, I discuss the quality of the empirical part of the study. I consider the appropriateness of the design of the cases with regard to the research interests (5.6.1); the quality of the collected data (5.6.2) and of the empirical findings (5.6.3).[201]

5.6.1 Design of the cases

There are three central challenges with regard to the quality of the design of the case studies. First is the question of whether the definition of the cases is appropriate with regard to the research questions asked (cf. e. g. Miles/ Huberman 1994: 278). The second challenge is related to my research position and double role. Third, I discuss to what extent the chosen cases are good (theoretical) representatives of the issue under study (cf. e. g. Yin 2009: 91).

First, the two cases addressed in this study have not been selected from a broader range of possible candidates, but were the only cases available. The most critical issue was that the UBA case was not considered a CIB&S case by all actors of the UBA *project*, as no modeling and simulation was actually carried out. This was solved by explicitly discerning between the empirically realized CIB(&S) case and the anticipated full application. Overall, the empirical research questions and the two cases are considered congruent.

Second, as described above, this study required me to deal with a double role. In the first role, as a team member, I was not neutral towards whether the approach worked out or not. To compensate

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199 We had audio-contact and were sharing slides. We decided against a face-to-face workshop to save resources.

200 Central questions were (see supplement E):

- „Are these insights surprising or not surprising?”
- „Do you share my impressions or not?”
- „Where does interpretation go too far—and where does it not go far enough?”
- „What did I overlook? Further forms, effects, factors?”

201 In the literature, case study quality is frequently discussed using the quality criteria of more positivist and quantitative research traditions [e. g. Yin 2009]) such as objectivity, validity and reliability, e. g., albeit by adding qualitative and interpretative reinterpretations (cf. also e. g. Miles/Huberman 1994). These principles of qualitative research were summarized by Lamnek (1995) as openness, communication, procedural character, and explication (in the sense of explicitness).

for this, at times I tended to be overcritical in my second role as an analyst. To balance these tendencies, I followed the advice by Miles and Huberman (1994: 226): "Keep thinking conceptually; translate sentimental or inter-personal thoughts into more theoretical ones." My specific interest into combined scenario methods has co-constructed the cases through my active involvements and also at times might have distorted my perspective. As described above, to counter the first type of bias, my impact on the cases is analyzed as such, that is as one among other impacts shaping the methodology. To counter the second type of bias, the review of case study reports by key informants was very helpful.

Third, the advice by Yin to strive for a multiple case design was fulfilled in part: This study has a two case design, albeit without using replication. Therefore, initially both cases are considered as illustrative and idiosyncratic cases (spotlights into the dark). The risk of this study is that they cover only a small part of the spectrum of interesting forms of application of CIB&S and are too idiosyncratic for one to be able to deduce much information from them about further applications. And certainly, as Geddes (1990) warned "[…] the cases you choose affect the answers you get." This phenomenon of selection bias was encountered in this study by the conceptual embedding and thus (indirect) comparison of the cases with the broader sample of prior experiences with combined scenario methodologies. Still, this broader sample in turn was biased through the dominant SAS-type approaches.

The conceptual frame (especially on combined forms) I developed indicates that I was lucky to be able to study two rather dissimilar and, as I later argue, also typical cases concerning the respective functions of CIB. Nevertheless, it is highly probable that there are further possible functions of CIB to support combined or integrated scenario construction that are neither empirically nor conceptually covered by this study, see Chapter 8, too. In sum, the sampling suited to an exploratory design.[202]

5.6.2 Collected data

The quality of the data collection is discussed first with regard to (content) validity, asking whether the collected evidence effectively matches what was conceptually intended to be measured (cf. Yin 2009: 41). Second, I discuss issues of objectivity, reliability and traceability, by asking whether the procedures of data collection, coding and data analysis could be repeated by a different investigator doing this same study (cf. Yin 2009: 45).

The data collection of this study was guided through the overall criterion of relevance that transported the perspective and the (working) definitions from the conceptual framework into the empirical realm. This helped to maintain the conceptually guided focus and to counter issues of selectivity, bias

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202 Based on the results of this study, further research might sample cases following a theoretical replication logic and perform hypothesis testing.

and subjectivity. Furthermore, I made use of multiple sources of evidence with regard to both independent and dependent categories. Especially the assessments of process outcomes were mainly based on data other than field notes, namely non-reactive process documents or the perspective of process participants analyzed through the interviews. With regard to the interviews, the communication with the process participants about the cases was successful overall, despite the multiple languages and cultures—in all senses of the term—involved. The few difficulties and misunderstandings that occurred,[203] were, in most cases, revealed either directly during the interview or at least considered during the later data analysis. Again, key informant review allowed communicative validation of the case descriptions.

The reliability and traceability of the data collection is supported by its documentation within the case study protocols (see supplements A and B), the reliability and traceability of the coding and of the analysis respectively, through the documentation of the code scheme and through the reports. In addition, a database was kept separately from the interpretations. Overall, I consider that the quality of the collected and coded data is sufficiently high.

5.6.3 Empirical findings

The quality of the empirical findings is assessed with regard to their internal validity, that is with regard to the question of whether conclusions are in themselves correct; and with regard to their external validity, that is with regard to the degree to which findings are generalizable (cf. Yin 2009: 40 ff.).

Basically, the internal validity of this study benefits from its conceptual ground, from the chain of evidence established from the research question through the protocols to the data collection, the databases, and finally to the data interpretation and conclusions (as recommended by Yin 2009). Nevertheless, it might be challenged by what is called the "holistic fallacy" (Miles/ Huberman 1994: 263), consisting in "[i]nterpreting events as more patterned and congruent than they really are, lopping off the many loose ends of which social life is made." In this study, this risk could arise with regard to the interpretation of patterns of effects within each case, and even more with regard to oversimplifications during the cross-case comparison of these patterns. Overall, I consider that the systematic discussion of the impacts of CIB as well as of multiple rival explanations provided a good basis from which to counter a too fast and too simplifying pattern finding. Still, findings based on higher degrees of abstraction (e. g. cross-case findings) need to be considered more carefully and

203 For instance, two of the (theoretical) concepts I used led to misunderstandings: "Transparency", which I related to the procedures of the scenario process, in Peru had a strong political connotation, inciting associations of "corruption" and "truth." Also the abstract term "scenario assumptions" was not immediately understandable to all interviewees and needed further explanation and concretization.

more critically by the reader with regard to their plausibility and coherence than those that are immediately empirically grounded (as within case findings).

The external validity of case studies refers to their *theoretical* generalizability. The later analysis and case synthesis shows that both cases are illustrative and typical cases of different functions of CIB within different forms of integrated scenario methodologies. This assessment and the overall findings in general are supported by the external validation achieved through the expert workshop. Further research is now required to test the validity of the findings of this study for other cases of CIB&S.

Chapter 6: Results from the UBA case

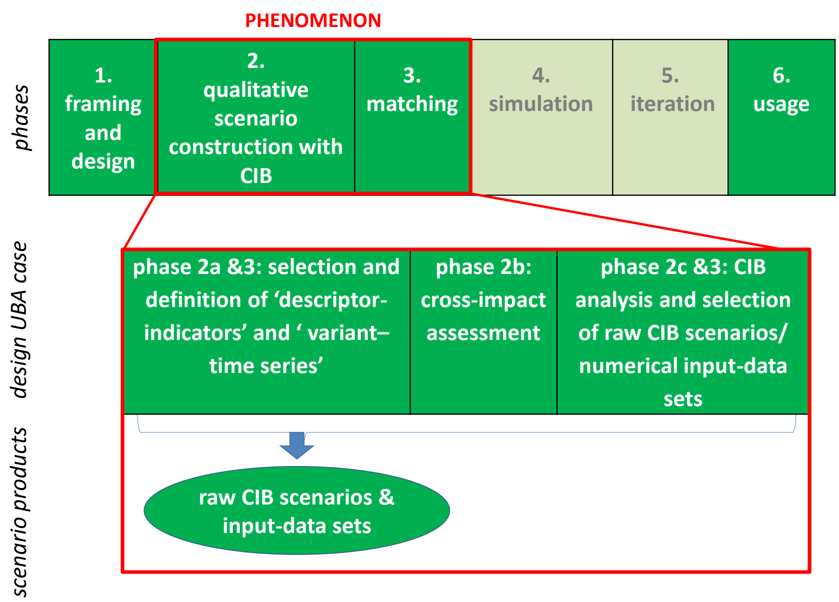
In this chapter I present selected results from the analysis of the UBA case (within case analysis). For the guiding questions of this case, its selection and design, see section 5.2. First, I describe the specific scenario methodology of the UBA case (6.1). Next, I focus on the form in which CIB was used in the UBA case (6.2). Third, I assess the effects of the use of CIB within the specific combined scenario methodology of the UBA case on scenario traceability (6.3) and scenario consistency (6.4) and interpret their logic. Moreover, I present evidence for other effects (6.5). Finally, I synthesize my insights and interpret the degree to which the effects in the UBA case are influenced by the CIB method itself, by other characteristics of the specific UBA methodology, and finally, by the specific form in which CIB is combined with numerical simulation models (6.6).

6.1 The CIB(&S) methodology of the demonstrator case

In the UBA case, no full CIB&S process, but a *demonstrator* application was carried out. It demonstrated the use of CIB to develop sets of numerical framework assumptions for environmental modeling and model-based scenario studies at UBA.

To allow the reader to follow the analysis and interpretation of the case, its methodology needs to be described. Therefore, the process is analytically divided into successive activities. In Figure 17, the phases of the CIB&S process that were covered in the UBA case are marked in strong green; the red frame delimits the phenomenon under study.

Figure 17: The phenomenon: CIB&S process steps and products covered by the scenario process (UBA)



First I briefly describe the immediate context consisting in framing and usage (6.1.1). Second, I present in more detail the different activities of the scenario process (6.1.2). Third, I characterize the methodology regarding its interplay between methods, actors and data (6.1.3).

6.1.1 The immediate context

6.1.1.1 Framing and design of the demonstrator application

In September 2010, UBA called for proposals for a special report on consistent framework data for modeling and scenario building at UBA.[204] The background of the call was the perception of the UBA project management that at UBA (and identically elsewhere) multiple model-based environmental studies co-exist. These studies are based on different models and on different input data assumptions (by using a range of different time series as input data) and result in a range of different results that are difficult to compare (see also chapter 5.2). The first aim of the UBA actors was thus to ensure the quality of scenario studies and to make the diversity of (framework assumptions of) quantitative model-based scenario studies at UBA more comparable.[205] In the special report, consistent sets of framework data should be developed and underpinned with time series (cf. DOC Call UBA).

Initially, the following design was planned: The ZIRIUS scenario experts, including me, decided to apply for the special report by proposing a demonstration project. The first aim of the scenario experts was to use the CIB method in a new form of application, namely to develop internally consistent sets of model framework assumptions (cf. DOC Proposal UBA).

Their second aim was to make the CIB method known at UBA (cf. FN Proposal writing). Due to my interest in CIB&S processes, I had introduced the idea of proposing an additional work package into the proposal. This should consist in carrying out simulations with the newly defined input data sets to demonstrate, what a difference a CIB makes. This was my specific aim linked to this proposal driven by my PhD project. Even if this additional working package was not included in the final proposal, the idea of a possible *full* CIB&S process was presented to key participants from ZIRIUS and UBA. This idea was, at least hypothetically, kept in mind during the entire project (cf. e. g. interview scenario expert V 16- 17, 63). The combination was anticipated or "*simulated*", as one of the scenario experts stated (V 16). ZIRIUS won the call to carry out a demonstrator project timed from October to December 2010, a project with a *short* runtime and under restricted resources. During a kick-off meeting (October 2010), its aims and methods were presented thoroughly by the scenario experts (cf. DOC PPT kick off).The aims of the project were fixed in the protocol of that kick-off meeting (cf.DOC Minutes kick off: 5): Next to testing and demonstrating the CIB approach to develop consistent

204 Consistent framework assumptions informing model and scenario analysis at the German Federal Environment Agency (*Konsistente Rahmendaten für Modellierungen und Szenariobildung im UBA*).

205 Note that the explicit aim of UBA was to increase comparability of framework assumptions—but not to ensure their complete harmonization within this short project.

frameworks scenarios for environmental simulations, an essential aim of the UBA project was to enable UBA to conduct its own CIB(&S) applications.
Effectively, the following design was implemented: It was agreed that the time horizon would be decided with regard to the available data. Initially, a time horizon of 2050 was aimed at (cf. DOC Minutes kickoff: 9). This time horizon of future developments and time series was lowered to 2030, since numerical data until 2050 was incomplete (cf. DOC Final report 201103: p.10).

Contrary to the proposal—and to the initial framing—purely qualitative descriptors were excluded for two reasons. First of all, because the CIB scenarios were aimed at support comparison and harmonization of *model* frameworks; second, because the number of descriptors that could be technically considered in the demonstrator project under limited resources was limited. Therefore, only quantitative *indicator-descriptors* were considered, meaning descriptor descriptions based on projections of indicators providing time series (cf. DOC Minutes kick off: 13).

The *actors* of the UBA case can be grouped into the 'CIB scenario experts', researchers from ZIRIUS; and the internal UBA actors, comprising the project management and the 'UBA scenario group', overall 12 actors, with five to eight per process steps, covering different disciplines and issue expertise. Some of these experts are environmental modelers themselves, others are not. The active involvement of the UBA scenario group that had been foreseen by the proposal was adapted to their effective availabilities (cf. DOC Minutes kick-off : 8). Still, a group of UBA experts participated from the kick-off workshop on during most process steps. Note that among the UBA actors, some actors were scenario experts (albeit not *CIB* experts) themselves. Furthermore, process-external UBA experts ('UBA guests') (n= 8) attended the final presentation of results at UBA.[206]

Overall, a short and numerical version of CIB was applied to construct numerical sets of framework assumptions, the so-called 'numerical context scenarios Germany 2030'.

6.1.1.2 Usage

The special report documenting the demonstrator project circulated at UBA and was published online (Weimer-Jehle/ Wassermann/ Kosow 2011). To my knowledge (at the time of the interviews with the UBA experts), the resulting sets of framework assumptions (indicator scenarios "Germany 2030") and the CIB&S method had not yet been used by UBA actors.[207]

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206 For an overview of the participation of individual actors during the different process steps, see Annex I.

207 Later, CIB was applied by UBA as a stand-alone method, for instance on the issue of European resource policy. The 'context scenarios Germany 2030' resulting from the demonstrator project were also effectively used later to compare framework assumptions of model-based scenarios in further projects (personal communication UBA project manager).

6.1.2 The scenario process in detail

6.1.2.1 Overview

The UBA scenario process was carried out in a quick and quantitative form, integrating the process phases of qualitative scenario construction with CIB (phase 2) and the matching (phase3) into one (cf. Figure 17 above).

To describe the UBA scenario process, I have analytically divided it into three central activities: The selection of descriptors and future developments (carried out through selecting model indicators and times-series), and thus including two subactivities of the matching, namely the specification and quantification (phase 2a & 3a,b); the cross-impact assessment ('phase 2b') and the scenario analysis with CIB and the selection of raw CIB scenarios, which were immediately underpinned with sets of numerical input data—and thus included the subactivity of bundling from the matching phase (phase 2c& 3c). Table 16 summarizes the elements of the methodology for each of these phases. Figure 18 visualizes the overall methodology and the interplay of the different elements. The phases are described in more detail in the following.

6.1.2.2 Selection and definition of 'descriptor-indicators' and 'variant- time series' (2a & 3a,b)

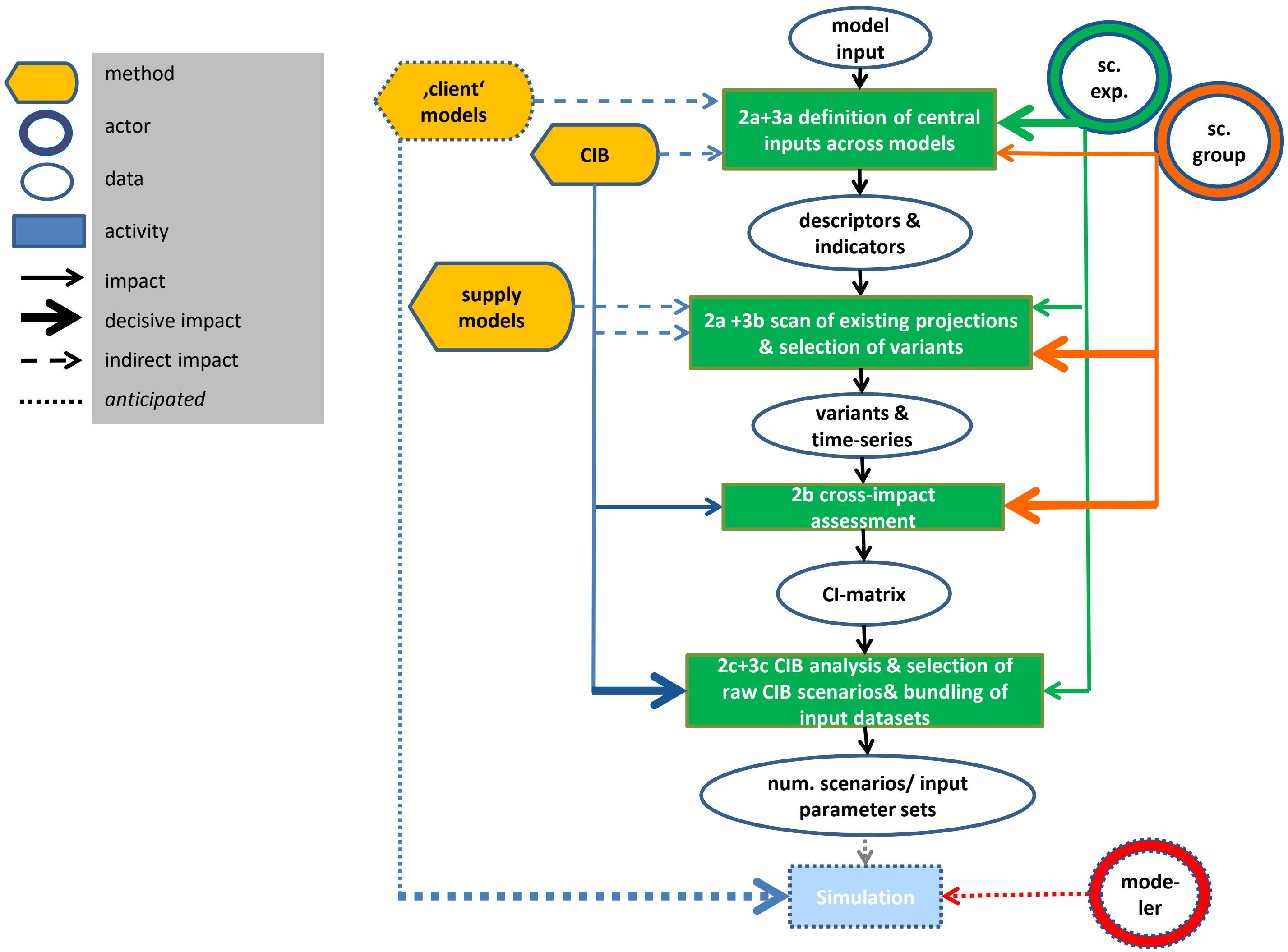
The *selection and definition of descriptors* was based on typical model input (indicators) used by UBA models, that means by environmental modeling and model-based scenario studies at UBA. With this in mind, UBA had provided the scenario experts with a list of typical indicators in use (for the studies analyzed for the selection of descriptors and future developments, see DOC UBA studies for indicator and TS selection).[208] The literature provided information on the typical input parameters used by the UBA models and on the variance of model assumptions used by different models with regard to input parameters as population growth or economic development.

208 At the time of the project in 2010, 17 different numerical models were used in model-based scenario studies at and for UBA (personal communication from a key informant).

Table 16: Overview of the methodology, elements with central impacts bold and underlined (UBA)

Activity	**2a & 3a,b Selection and definition of descriptor-indicators and variant- time series**	**2b Cross-impact assessment**	**2c & 3c Balance analysis and selection of raw scenario sample and input data sets**
Objective	*What context indicators are typically used and with what range in current environmental modeling and model-based scenario studies at UBA?*	*Do descriptor variants have impacts on each other? If yes, are these hindering or promoting impacts, and how strong are they?*	*What are (central) internally consistent configurations (i.e. scenarios) of the matrix "Germany 2030"?*
Timing	Oct. 2010	Nov.2010	Dec. 2010- Jan. 2011
Actors	**<u>UBA project management, Scenario experts</u>** (UBA expert-group/ scenario group).	**<u>UBA expert group/ scenario group</u>** Scenario experts.	Scenario experts. UBA project management. UBA Scenario group external UBA experts.
Methods	Desk research (Review of current scenario studies). Consultation between UBA and scenario experts. Video-conference. (CIB anticipated).	Individual survey to elicit individual expert assessments on (parts) of the matrix. (Desk research). One–day workshop for group discussion of dissent CIB (specific form of impact assessment).	**<u>CIB balance algorithm,</u>** <u>ScenarioWizard</u> **(<u>CIB software</u>).** Final workshop. Report writing.
Data	List of typical input indicators and the range of their projections (current model-based scenario studies at UBA).	Expert judgments (1. from individual survey and 2. from group discussion of dissent) based on discussion of different mental models on interrelations.	Matrix "Germany 2030". Ex-post reconstructed justifications for impact assessments.
Product(s)	*List of 10 typical descriptor-indicators, most of them with the three variants high, medium, and low; as well as time series on context assumptions 'Germany 2030'.* *Documented in descriptor briefs.*	*N= 5 matrices (3 only partly filled in).* *Condensed into one mean matrix.* *Final matrix Germany 2030.*	*Raw CIB scenario and input data sample, comprising n= 6 types of scenarios.* *Final report, including visualization of impact logic through impact diagrams.*

Figure 18: Visual summary of the CIB(&S) methodology, simplified overview (UBA)



This selection of indicators was—as planned—made in a rather quick and pragmatic way without discussing the quality of data behind each descriptor in depth (cf. DOC Minutes kick-off: 5). Furthermore, the selection of *descriptor-indicators* was carried out mainly by the CIB scenario experts and by the UBA project management. Scenario expert W (interview W 52) reports that at some moments, it was necessary to define a single descriptor by choosing one from several similar but not identical indicators that were used by different models.

After the kick-off workshop, a first list of data (indicators and alternative time series) was prepared by the scenario experts (cf. DOC Indicators and time series for selection), which was then discussed during a video-conference. During this event, the *UBA scenario group* had the possibility of a say, too (cf. DOC Minutes video conference).[209]

Finally, ten descriptors and their corresponding indicators were chosen (see Table 17) without much discussion, except for two descriptors:

- The *total material requirement* (TMR) was recognized as being a sub-optimal indicator, compared with other indicators that include effects of global trade. Nevertheless, it was chosen because, for other indicators of material flow, *no* prognoses or time series on future developments were available (cf. interview UBA expert A 65 as well as Weimer-Jehle/ Wassermann/ Kosow 2011: 9).
- The indicator *GDP* was discussed as a limited measure of prosperity and well-being, but was chosen because it is one of the very typical drivers of environmental and energy scenarios (cf. Weimer-Jehle/ Wassermann/ Kosow 2011: 9).

The selection of *alternative descriptor developments* (variants and time series) was made at the same time and on the basis of the same data as was the selection of descriptor-indicators. The range of individual input-parameter developments assumed by the existing UBA scenario studies had previously been analyzed by the scenario experts. Then its full range was used to allow the CIB context scenarios to take up the greatest range of alternative future developments assumed by the different UBA models. The overall range taken into account for each descriptor development was thus predefined by the existing time series of the corresponding indicators. During the videoconference, for every indicator-descriptor a high, a medium, and a low development was chosen.[210] Scenario expert

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[209] Overall, the final selection of descriptors went very fast, compared with other CIB processes (cf. interview scenario expert V 25, 30) because the participants' interest in the method might have outweighed their interest in contents, where in non-demonstrator applications more dissent between different modeling groups might exist (interview V 30): *"[...] I would say that is a point where it has become particularly clear that it is a demonstrator, and the important thing is to carry out the process fully, so that everyone has a sense of how it works and what kind of results come out of it. But it did not matter that the outcome is perhaps not the optimal one."*

[210] Due to the demonstrator character, the ideas on future developments extracted from the literature, i.e. existing time series were not discussed in-depth or fundamentally questioned. UBA expert B remarked (cf.

W remarked (interview W 55) that for some developments, such as population growth, the high and low variants chosen for the CIB are far more extreme than those, which are predominantly used, for example in energy modeling: *"[…]. And then I noticed—nobody expects the top and the bottom [variant]. That means, you're so far away from everything."*

In contrast to this single remark, a clear need to consider even *more* future variance was expressed by the UBA scenario group, that is a need to consider more diverse or more extreme developments than represented by the pre-existing time series. For instance, UBA experts proposed during the kick-off workshop to introduce a wild card analysis to expand the range (cf. DOC Minutes kick-off: 5) .[211] This need *to* consider more future variance remained visible during the videoconference ten days later. The changes UBA and ZIRIUS agreed to make to the initial list of descriptors and variants mainly referred to the definition of the variants. All changes made were in favor of more extreme alternative developments, instead of more conservative ones (cf. DOC Minutes video-conference: 19-24)[212] With regard to the descriptor of economic development, more variance was added, too—and in a fairly qualitative form—by defining a weak and at the same time volatile development of the GDP. This variant is the only one that is not directly taken out of one of the studies supplied by UBA and it is the only one that is mainly described in a qualitative way.

Due to the selection of descriptor-indicators and variant-time series, no ex-post translation of qualitative scenario assumptions into numerical model input (no matching) was necessary: Time series had been present from the beginning.[213] The D&V list contained (almost) *no qualitative aspects* but had been directly defined in a quantitative way. This choice certainly saved the difficult translation of qualitative statements into numbers. But on the down side, it refrains from a qualitative characterization of the scenario scope and space, which would have been possible with CIB.[214]

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interview B 134) that this would have been required in a different form of application, namely in an application less focused on quantitative modeling. (Interview B 134: *"Where our approach has relied very much on the results which we have effectively assessed by using other forecasts and which we have given less thought to. In this respect, we have slightly limited ourselves, but the fact that it is intended for quantitative model work makes it OK in this context. In another context, I would actually use the forecasts, but I might also think about them again."*)

211 In the following process, two wild cards were drafted by individual UBA experts : wild card A on strongly sinking temperatures and wild card B on an economic crisis (cf. Weimer-Jehle/Wassermann/Kosow 2011: 78 ff.). These remained rather a side product in the following scenario analysis.

212 "Living space per capita: *a further scenario with the largest possible variance is supplemented by ZIRIUS, where possible […] Oil price: for the variant "high," ZIRIUS is looking for higher values to obtain more visible variance*."

213 No detailed *specification* with individual and specific UBA models as 'clients' for the CIB input parameter sets had been foreseen or carried out. This potentially strong effort was not considered during the demonstrator project as Expert A pointed out (Cf. interview A 80). Still, such a specification, i.e. an adaptation of the input parameter sets to the specific numerical model's needs and requirements was recognized as necessary for further CIB&S applications (Cf. interviews D 115- 117, A 80, V 16).

214 Interview UBA expert A 96: "*The method was unfortunately also only limited in this application, because we have also confined ourselves to a more quantitative form of logic ('high,' 'medium,' and 'low'). It could be much more interesting if you started from real descriptions and qualitative considerations. If we had chosen a somewhat softer scenario*

In sum, 10 descriptors with 2-3 variants each were selected (a summary overview is given in Table 17). They were textually and graphically defined and documented by the scenario experts in so-called descriptor briefs. These contained short definitions and justifications of the chosen descriptor-indicators, and assumed variant time series, including their sources, on about three pages each (cf. Weimer-Jehle/ Wassermann/ Kosow 2011: 50 ff.). Overall, the selection of descriptor-indicators and variant-time series was an *actor*-driven activity, strongly framed by the pre-selected *data* on typical model input.

Table 17: List of descriptors and variants (D&V) "Germany 2030" (UBA)

(My representation based on Weimer-Jehle/ Wassermann/ Kosow 2011: 11.)

Field	Descriptor	Variants
Socio-economic development	APopulation growth	a1 low decrease to 81 Mio a2 moderate decrease to 79 Mio a3 strong decrease to 76.6 Mio
	B Living space per capita	b1 strong increase to 50.4 qm b2 low increase to 44.2 qm
	C Gross domestic product (GDP)	c1 strong increase to 3509 G € (ca. 1.6%a) c2 medium increase to 3120 G € (ca. 1.2%/a) c3 low increase to 2830 G € (ca. 0.8%/a) c4 low and strongly volatile growth
	D Oil price	d1 strong increase to 127 $/b d2 medium increase to 110 $/b d3 constant at ca. 63 $/b
	G Transport performance: passengers	g1 considerable increase of 32% g2 moderate increase of 10% g3 small decrease of 5%
	H Transport performance: goods	h1 very strong increase of 69% h2 strong increase of 53% h3 moderate increase of 34%
Resource intensity	E Consumption of primary energy	e1 small decrease to ca. 13400 PJ e2 medium decrease to ca. 11000 PJ e3 strong decrease to 7700 PJ
	F Total material require-ment (TMR)	f1 increasing consumption to 7200 Mt f2 more or less stable consumption around 6400 Mt
	I Nitrogen excess of agri-culture	i1 stagnation i2 decrease of 20% (ca. 1%/a) i3 decrease of 30% (ca. 1.6%/a)
Environmental change	J Climate change	j1 a little warmer—considerably wetter j2 moderately warmer—a little wetter j3 considerably warmer—a little wetter

approach, we would certainly have covered a broader area for future developments. This is the case with SAS, but then you have the problem of transformation…"

6.1.2.3 Cross-impact assessment (2b)

The impact assessment was realized in two consecutive steps, first through an individual survey of the UBA experts, and second during a workshop inviting these experts to come together as a scenario group.

In the first step of the cross-impact assessment, individual expert assessments were collected through an email survey. A short introduction to the method was offered during an internal UBA workshop during which the participants received a blank CI-matrix. To this was added a page of instructions on how to fill it in (cf. DOC CIB matrices over time). It had been agreed prior to the survey that experts should fill in only those parts of the matrix for which they felt they had the necessary expertise. The survey resulted in five matrices: two complete ones, one filled by ¾, and two in which only a single specific issue had been addressed (cf. DOC CIB matrices over time).[215]
There were some specificities concerning the (non-)continuity of *participation* of the UBA experts.[216] First, from the in total eight UBA experts, five had not followed the preceding steps of the process (framing, selection and survey), so they were considered, at least by the scenario experts, to be newcomers to the method and to the impact assessments made by others. At the same time, three of the UBA experts who had provided matrices, were *not* present during the workshop, and thus could not explain their individual impact assessments. Second, during the workshop itself, two of the newcomer participants did not follow the entire workshop but came in for only a limited period of time. When they were present, the group turned their attention to the judgment groups of the newcomers, meaning the judgments that the newcomers had expertise in (cf. interview scenario expert W 105). This might have hindered a systematic discussion of the impact assessments further, since apparently some judgments were revised without perhaps revising others in return, as scenario expert W observed (interview W 105). Overall, due to the demonstrator character of the UBA project and its method-training component, interest among the participants in the general logic of the method might have outweighed interest in the content. It apparently did so for the selection of D&V (see above), and this also might have reduced the depth of the discussions of the impact assessments during the cross-impact workshop.

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215 One with regard to transport, passengers and goods, and the other one with regard to nitrogen excess of agriculture

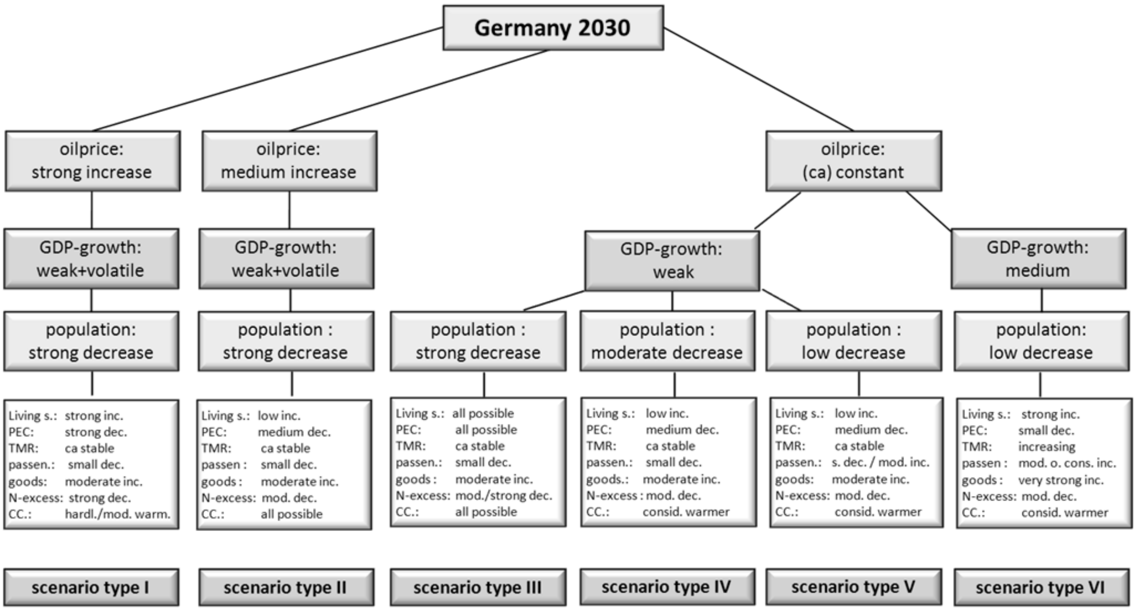
216 For an overview of the participation of actors during the different process steps of the UBA case, see Annex I. This participation pattern might be explained by the individual availabilities of the UBA experts (and thus by reasons outside this process). At least, the shuffling during the one-day workshop did not entail a drop-out of those who had participated during the earlier phases and who had provided the matrices, since most of these participants, in addition to those who participated during the workshop, attended the final presentation.

6.1.2.4 Scenario analysis and selection of raw CIB scenarios and of input data sets (2c & 3c)

With the support of ScenarioWizard, the scenario experts determined internally consistent configurations of the impact network and grouped them into a scenario table covering six types of scenarios see Figure 19).

Figure 19: Completely internally consistent constellations, grouped into a scenario table (UBA)

Source: Weimer-Jehle/ Wassermann/ Kosow 2011: 25

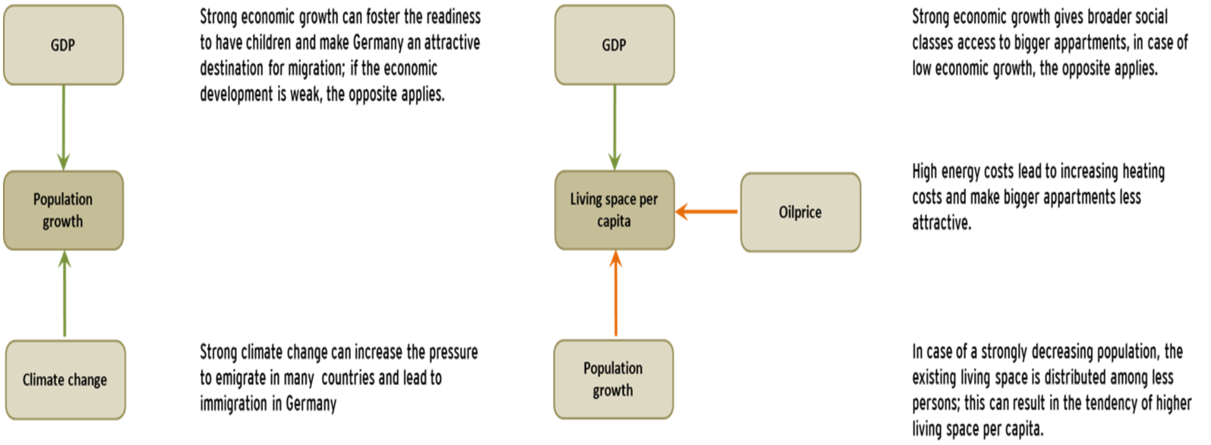


To visualize and explain the interrelations coded in the matrix in a simpler way, *impact diagrams* were developed for the final workshop and report. In the different influence diagrams, the role of each descriptor changes from explaining variable to explained variable (cf. Figure 20 on population growth). The textual explications of the impacts were (mostly) ex-post reconstructed from the argumentation during the CI-workshop by the scenario experts, though some had been documented by the UBA experts within their individual matrices.

The resulting scenario configurations were reported to the UBA during a final workshop organized by the UBA, with sixteen UBA experts (cf. FN final workshop). They were published in the project report, together with the underlying time series (cf. Weimer-Jehle/ Wassermann/ Kosow 2011: 18 ff.).

Figure 20: Impact diagrams for individual descriptors, extract from CIB "Germany 2030" (UBA)

Source: Weimer-Jehle/ Wassermann/ Kosow 2011; Legend: green arrow: promoting impact assumed, red arrow: hindering impact assumed.



6.1.2.5 Anticipating further phases of a full CIB&S process

In the UBA case, no full CIB&S process was planned or carried out. Thus, for instance, the new sets of input data resulting from the CIB were *not* actually used for comparisons with input data sets currently used by individual models or even for new simulation runs with new input data sets—and no iteration occurred.[217] These further steps had been only theoretically considered by the scenario experts, and especially by me, as *potential (future)* applications. Still, at least some of the indicators and time series that were used within the CIB analysis were model-based or simulation output themselves.

6.1.3 Characterizing the overall methodology: social organization, technical design and cognitive dimension

Now, taking a step back and considering the overall methodology, the UBA case is characterized regarding its *social organization* (who is doing/ deciding what?), *technical design* (what methods and techniques are applied?), as well as *cognitive dimension* (what data is used, processed and produced?) and overall *conditions.*

6.1.3.1 Social organization: a coalition of interest between scenario experts and UBA

The process was supported through a *coalition of interests* between the UBA experts' interest in methods, the scenario expert's interest in making CIB known at UBA and of testing new forms of applications—and my own interest in testing combined CIB&S applications. This coalition led to a high degree of engagement from both sides and close collaboration. The *initiative* for the process did not come directly from the environmental modelers. Still, the perceived need for more reflection of context assumptions was a starting point to the project.

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217 Some feedback and refinement occurred during the selection of descriptors and of their future developments and during the writing of the descriptor essays.

The UBA project management organized all events and the expert participation at UBA (selection and recruitment), contributed to the design of the process (e. g. through the call for tender and work description) and to the preparation of the content of the process (e. g. through the pre-selection of studies and indicators). The scenario experts brought in their method expertise, co-designed and facilitated the process, supported the events in terms of its content (data research), carried out the CIB analysis and provided documentation. The UBA scenario group was strongly involved in the process step of impact assessment, but only partially in the selection of D&V. It was not actively included during the analysis of the matrix and the selection of scenarios. Thus, it was an *expert-group* providing data and learning about the method rather than a *scenario group* constructing its own scenarios.

6.1.3.2 Technical design: typical model in put data processed by a CIB, which is using numerical D&V

In January 2010, 17 different mathematical models were in use in UBA (funded) environmental modeling and scenario projects.[218] These models were using a range of numerical framework assumptions for scenario calculation. Still, these models did not play a direct role during this case, but a strong indirect one. They were the anticipated 'client' models, and - in some cases at the same time - data 'supply' models, *providing* indicators and time series. CIB was used in a quick form by using the models' numerical indicators and projections—purely qualitative descriptors were excluded. CIB replaced more intuitive and less systematic approaches currently used for input data selection and composition in the UBA model group. In addition, various other techniques were used in the UBA case from data collection to facilitation.

6.1.3.3 Cognitive dimension: qualitative analysis and synthesis of quantitative model input

The pre-existing input indicators and time series were reconsidered, explicitly verbally and numerically defined and justified as D&V, and then put into interrelations through the CIB impact assessment. These expert assessment led to a cross-impact matrix, that is an impact network (a form of conceptual model), linking the numerical assumptions on future context developments in semi-formalized way. Overall, the process started with numerical information that was qualitatively analyzed during the formalized but qualitative CIB process and finally led to numerical input data sets ('quantitative context scenarios'). These are not qualitative pictures of possible futures of Germany 2030, since more qualitative assumptions remained implicit (see section 6.3).

[218] Source: personal communication from a key informant.

6.1.3.4 Conditions

Finally, the UBA case took place under the specific conditions of a demonstrator, in which the interest in method outweighed considerations of content. Furthermore, the few resources available were counterbalanced by the strong motivation and engagement of the UBA management and scenario experts.

6.2 Characterizing the form of combination of CIB(&S): CIB as an analyst of context assumptions of a group of models

In the UBA case, no full CIB&S process was carried out. Nevertheless, this CIB(&S)-like process can be characterized with regard to the *form* of the combination of CIB and numerical models that was *effectively* realized during the demonstrator. Furthermore, one can characterize the type of the combination that was *anticipated*, namely the use of CIB within a group of models that are then further processing the CIB-generated input data sets. References to this hypothetical form of application are in marked the following sections by *grey and italic type.*[219]

6.2.1 System representations: qualitative system analysis of numerical model assumptions on future social contexts

In this case, CIB is used for a qualitative systems analysis of numerical model assumptions on future social contexts. The conceptual CIB model represents the assumptions on possible future developments in the full range taken into account by the different numerical models. Furthermore, the conceptual CIB model represents (assumed) interrelations between these developments, which are exogenous for many of the models, in a semi-formalized way.

Division of labor is established between societal context and scenario uncertainty, represented by the CIB versus numerical systems knowledge that is displayed in the mathematical model(s). Note that the room for qualitative system representation is limited on the one hand to the textual definitions of indicators and variants for which, within the descriptor briefs, a qualitative (re-)interpretation is given; and on the other hand to the impact assessments on assumed interrelations between developments and their justifications.

The *scope* of the conceptual CIB model and the resulting scenarios is broad, covering socio-economic issues, resource intensity and climate change; their granularity is low. The scope is distinct from the scope of the mathematical models that are anticipated as client models. These models cover subsystems or sectors in detail (with very varying scopes and degrees of granularity).

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[219] For the definition of the dimensions, see chapter 4.2.2, a summary of the characterization is given in Table 18 in section 6.2.4. The following characterization is based on process documents and observations. It was validated by two key stakeholders

The overlap of the CIB with the numerical (client) models at the UBA varies, depending on the different numerical models. CIB uses projections (time series) that are used by various client models. But not all models need *all* of the assumptions. On the contrary, most of them only need some of the input information. Their individual information need in turn only partially overlaps the other models' needs. Furthermore, although most of the parameters of the CIB scenarios are exogenous for most of the UBA client models, some of the CIB descriptors are endogenous parameters calculated by some of the UBA models, as for example the population growth or the GDP. Thus, some overlap is possible between the descriptors and the interrelations represented by the CIB network on the one hand side, and parameters that are endogenous parameters of some of the models on the other.[220]

In sum, in the UBA case, CIB provides a *qualitative* context model and system analysis of *numerical* model assumptions on future contexts. CIB is used to qualitatively analyze interrelations between individual model inputs representing the future uncertainty and complexity of model contexts.

I assume that in the hypothetical full application (within a model group using the CIB input data sets), the system representation of CIB would be comparable and would also focus on quantitative "coupling descriptors" (Prehofer et al., forthcoming) and less on additional—and only qualitative—context factors.

6.2.2 Position: models first

Even though numerical models were not actively used during the process under discussion, their position can be characterized as 'models first'. This holds true with regard to their timing and dominance such as their role in determining and structuring the process.

With regard to *timing*, client and supply models pre-exist and precede the CIB analysis (cf. also Figure 21 below). First, the (potential) client models themselves, that is those models (M1-n) belonging to the group of UBA models, whose input indicators were chosen, and which are older than the CIB analysis. Second, the CIB analysis is based on *ready-made data* on possible future developments that comes from *prior* studies, which themselves are often modeling- and simulation-based. Most of the projections are not made by the UBA models themselves but originate from various other types of models from outside the UBA group of models ('external supply models').[221]

In an anticipated use of CIB within such a model group beyond a demonstrator application, the (most simple form of timing would be the following: Projections are generated with supply models (and used by the client models) (t1). Through the variance of their results, they inform on the range of pos-

[220] This situation was assessed as complex by some of the UBA interviewees (e. g. interview A 80, FN final presentation).

[221] Types of external supply models range from expert guesses through trend extrapolation to simulation models.

sible future developments that are then considered during the CIB analysis (t2). Through this CIB analysis, indicator-based context scenarios are constructed by analyzing potential interrelations between future developments and by selecting internally consistent framework assumption. Finally, these 'context scenarios' are used to orient and adapt the framework assumptions for the different UBA (client) models and their simulation runs (t3).

Although no numerical model has effectively been used in this case, numerical models have *determined* or at least *strongly structured* the scenario construction process in several ways: First, CIB was used *instrumentally* to reflect the range of input data and the composition of input data sets that are currently already used by the models. No narrative storylines are being constructed; no stand-alone qualitative scenarios are sought. Quantitative raw CIB scenarios serve to compare, to construct, and to manage model input. Scenario *content* is supplied by models and/or driven by model requirements. CIB has impacts mainly on the level of scenario and sample *structure*.

Second, the models have a strong influence on the definition and selection of the system elements (that is descriptors) taken into account by the CIB analysis: Descriptors and indicators are chosen that fulfill two conditions. First, they are needed by pre-existing numerical models, meaning the selection is driven through model demand; second they are readily available in numerical form, meaning the selection is driven through what data is offered by supply models.

Third, the models also define the range of future developments taken into account: The range of future developments is taken into account, which is provided by the model outputs and projections already in use. [222]

Fourth, the model context is qualitatively analyzed as a system during the CIB. But no independent definition of (potentially also relevant, but perhaps qualitative) elements of the model contexts has taken place. Instead, the available data was important to structure the process of selection of descriptors and therefore, the overall design of the CIB impact network.

Fifth, and this time hypothetically, the supply models could provide information or assumptions on interrelations between descriptors that are relevant for the CIB. Under the condition that these are is explicit and accessible; the CIB could take over this information in semi-formalized form. For instance, one could translate correlations implemented in the numerical models into cross-impact assessments on promoting or hindering interactions at a chosen strength (see the next dimension coupling for more details on this aspect).

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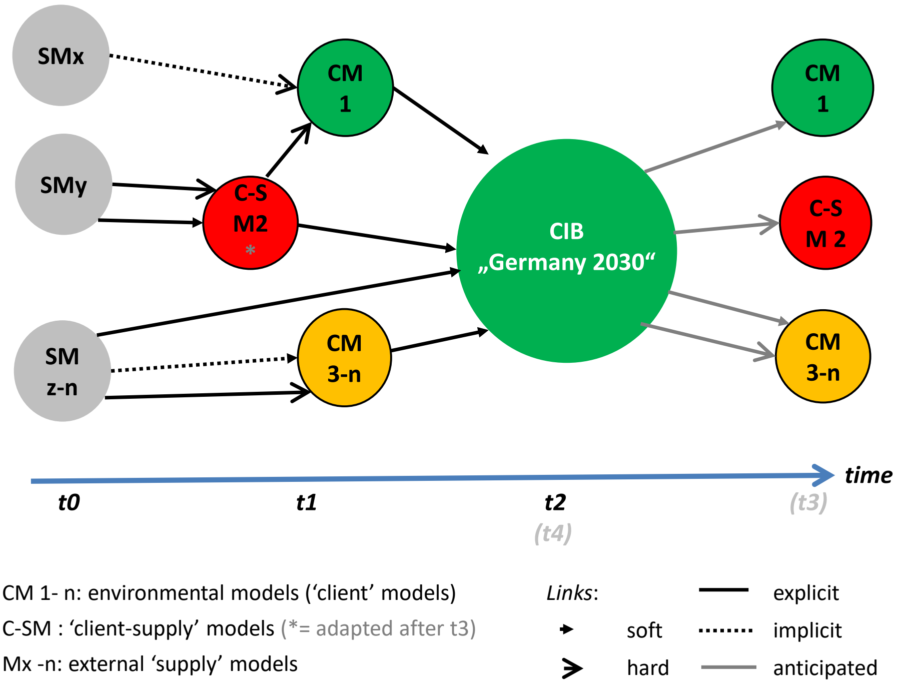
[222] With the one exception of the fourth variety for the GDP development "c4: small and strongly volatile growth" which is qualitatively described and not based on pre-existing studies or hard data. As shown above, this development was added by the group of scenario experts due to a need to cover more of the theoretically possible range of GDP developments than were then covered by the pre-existing projections.

Figure 21: Form of combination of CIB and numerical models, focus on timing and link (UBA)



6.2.3 Link: link from supply and client models to CIB, anticipated link from CIB to client models.

First (see Figure 21), CIB is linked to the input data currently used by the client models (CM1-CMn). This is rather a soft link, as the models inform the CIB, but no direct and no automatic coupling occurs. Instead, decisions on indicators and specific time series are made during the CIB process.

Second, this input data comes (explicitly or implicitly) from further external supply models (SMx-y) or from internal models that have the double role of 'client-supply' models (C-S M2), which at the same time provide input data to the model group and are potential future clients of the CIB for other inputs. The information provided by the supply models was, in the UBA case, on the level of scenarios only—but, and this holds true especially for client-supply models, the models might also inform CIB on assumed interrelations between at least two CIB descriptors. This information would then be situated on the level of internal model structures.[223]

Third, and this is anticipated only, the raw CIB scenarios (numerical framework sets) could be linked to the client models, either in a soft way to compare their model input with the scenario sets pro-

[223] The interrelations defined by the supplier model could be taken over—albeit in a semi-qualitative form—by the CIB analysis. If different supplier models provide diverging or even incompatible assumptions on interrelations, CIB could test the consequences of both by comparing the sets of scenarios resulting from alternative matrices. UBA Expert A raised concerns with regard to this problem (Interview A 83): *"In the end, the quantitative models also contain the causal relationships, and in principle you have to know, you have to know whether the interconnection fits, you have to look very carefully, and consider, what is exogenously and endogenously, what factors are linked, where and how. Several ''stalks' look out of such a model and then you have to decide, with which ones where you start."*

posed by the CIB,[224] *or through a hard link, if client models take over the CIB-provided input data sets for their modeling and simulation. Note that in case of client-supply models, such a hard link might lead to feedback, as the model output provided by these models to the model group might change in function of the new input data.*[225]

6.2.4 Overall: form of combination and function of CIB

The combination of CIB with simulation models in this case is in part only anticipated, and no full combined scenario process was realized. Therefore the process can be characterized as a CIB(&S) process only. Nevertheless, it makes it possible to learn about this *type* of application of CIB within a group of models going beyond this demonstrator: CIB in this form of combination serves to reveal, to compare, to manage, and potentially to harmonize the different indicators and time series used by the various client models (and provided by the different supplier models and data sources). CIB is not an equal partner within a group of other models but rather a *service provider* to a model group.

Table 18: Form of combination of CIB with numerical (simulation) models: CIB as a service provider and analyst of context assumptions for a group of model (UBA)

Dimension	Operationalization	UBA
System representation of each component How do the different system representations look like?	**Division of labor** between CIB and the model(s); qualitative vs. quantitative representation.	**CIB**: societal context and scenario uncertainty (in *numerical* form: *qualitative* system representation is limited to a) the textual redefinitions of indicators and variants (in the descriptor briefs e. g.) and to b) the impact assessments and their justifications) (CIB with coupling descriptors only). **Numerical models**: numerical systems knowledge.
	Scope (also: What is in- what is outside? endogenous vs. exogenous?) **and granularity.**	**Rather distinct scopes:** • CIB: broader context developments of environmental issues in Germany until 2030, very coarse (little detail) (10 descriptors, with 2-4 variants). • Num. models: subsystems/sectors in detail (very varying degrees of granularity).
	Overlap between the system representations.	**Overlap varies, depending on each model…** • Most of the numerical client models require only some of the framework assumptions bundled by the CIB, with overlap and differences between the input requirements by different models. • For some models, some of the projections CIB provides are exogenous, some are *endogenous* ➔ varies strongly! (e. g. whether GDP is calculated by model or used as input). In these cases, more overlap between the CIB and the numerical model's system representation is given.

224 The sets of input parameters determined through the CIB analysis might not match the combinations of input parameter initially used by a model at the time when it supplied data (before t1, "t0"). These potential inconsistencies have to be dealt with; a comparison of the assumptions underlying the input parameter sets in t1 with the assumptions underlying the input parameter sets in t3 might be necessary.

225 The use of new sets of input parameters, adapted to the CIB sets, may have consequences for the model output calculated (in t3) and iteration including the CIB (t4) could become necessary.

Dimension	**Operationalization**	**UBA**
Position of both components What role do both component play with regard to each other and in the overall process?	**Timing**: What comes first?	**Client and supply models pre-existing and preceding CIB** Ideal typical timing: Supply model provides projections (used by the client models) (t1), these are analyzed and synthesized by CIB into context scenarios (t2) that are used to compare, and potentially adapted input data sets are used by the client models (t3).
	Dominance/ structuring the process/ central **benchmark** for adaptations.	**Models structure the scenario process** through model requirements and data availability that pre-structure selection of numerical D&V ('content supply'), CIB impacts scenario and sample structure only.
Link between the components How are CIB and model(s) linked to each other?	Type and level of **coupling.**	CIB takes over input indicators- and time series used by the client models (explicitly and implicitly provided by supplier and client-supplier models) (soft link). *CIB could also take over information about interrelations between descriptors, if a model has endogenized these)* *CIB-produced input data sets could (but this step is only anticipated) be linked in a soft way to compare them with a client models' inputs, or in a hard way when the client model actually uses them as framework data.*
	Iteration.	*Iteration might be necessary where client-supply models use new CIB input data sets, and this changes the output they supply to the other models and to the CIB.*

6.3 Scenario traceability: Assessments and interpretation of effects

What effects does the use of CIB(&S) have on the traceability of the construction of numerical sets of context assumptions in the UBA case? First, I describe what level of scenario traceability was perceived by the interviewees (6.3.1). Then, I propose an interpretation linking the degree of traceability back to (the interplay of) different elements and characteristics of the specific scenario methodology of the case (6.3.2). For brevity, only few original statements are included in this summary.

6.3.1 Traceability assessments

Has the process of constructing sets of framework assumptions been perceived as traceable by *internal* and *external* actors of the UBA case? All interviewed internal actors had *some* prior experience with either qualitative or quantitative scenario analysis, at least as passive recipient users. Five of them have already actively used approaches out of one of both schools. In addition, five actors declared themselves familiar with systems thinking, the others remained silent with regard to the issue. Note that six out of eight have a preference for systematic approaches over intuitive ones. Thus, one could assume they might be a priori biased in favor of the CIB approach. For an overview of the actors' characteristics, see Annex M. In addition, through observation I collected some feedback from external actors, who had either participated during the final presentation at UBA, or were the editors of the final report at the Federal Ministry of the Environment (BMU).

In the following, I present issues of comprehensibility (6.3.1.1), of explicitness of assumptions (6.3.1.2) and of traceability of scenario composition and sampling (6.3.1.3).

6.3.1.1 Easy to understand?

Was the CIB method perceived as comprehensible and was it understood? Overall, the CIB method was assessed as comprehensible, but as not an easy method: Although rated as easy in principle by the UBA experts,[226] the practical *application* of the CIB is perceived as not unchallenging. UBA experts mainly report difficulties with the CIB impact logic, since these require that one do the following.

a) Consider impacts in a specific *direction.*[227]

[226] The general idea of the CIB method is assessed as rather easy to understand by most experts, e. g. interview expert A 44: "The method in itself is deceptively simple at first glance. It is very transparent and very clear"—as well as Interviews UBA experts B 69; C 29; D 48; and F 34.

[227] The difficulties experienced with the CIB impact assessment are linked either to the challenge of considering the direction of impacts correctly: What is influencing what and what is influenced by what? As expert F stated (F 34): "I can imagine if you do this often that, if you are more involved […], there is not such a mess, so what works now, what must I be thinking now? Is this the effect, or that the effect or ...? I found that quite difficult the first time." In the same line, expert D states (D 48): "First, I found it quite easy. If you think about it in more detail, it will keep on being difficult. You always have to ask the question: Am I thinking along the right lines? Then it gets a bit complicated. But it's okay […]." This issue is also mentioned by UBA expert C (82) and scenario-expert W (138).

b) Assess *direct* impacts only, which clearly presented some difficulties.[228]

c) Do the assessment correctly not only once but repeatedly.[229]

This was true especially during the email survey, as the individually filled matrices reveal.[230] To apply the CIB impact logic correctly is a sort of hurdle that participants had to surmount—this was also perceived by the scenario experts: *"[…] in practice, all disciplines actually first have to jump over an abyss"* (V 118).[231] Insufficient understanding of the method's impact logic led to technical uncertainties and to mistakes in the matrix—for instance, when the direction of impact direction was mixed up or when indirect impacts were coded, as for example UBA exert C 54 observes: *"I have the feeling that many colleagues have not gone quite as far, have not fully understood the rules of the game and therefore they did not really know how to do it."* , see also Annex O. Overall, the method was characterized by the scenario experts as an imposition that all actors needed to get involved with.[232]

Furthermore, a rather *roundabout, or vague, understanding* of CIB's consistency logic can be observed among most of the UBA experts, and it is not sure that the balance algorithm was fully under-

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228 The difficulties experiences during the impact assessment are also linked to the challenge to consider *direct impacts only* i.e. *to exclude indirect influences* that are expressed by other descriptors of the matrix as expert F stated (F 34): *"And then just to think is that a direct effect or an indirect effect and to review this matrix […] That is something that I found unusual. But what is going on was understood, but having to keep on imagining what it is like for each factor … well ... is that now indirect or direct? So what actually still works, well ... was very expensive if you do it for the first time, delve into it first."* This problem is also mentioned by experts C and W (C 29, W 215).

229 UBA experts report that *the difficulty of CIB lays in the multiplication and repetition of the individual questions.* UBA expert A 50: *"So the individual question is always easy, relatively easy in comparison, but because it is a multiplication, like many individual questions I have to ask myself, well, the complexity of this method comes from another angle, if we can put it like that."* To apply the method correctly, *concentration* has to be maintained, UBA expert A 44 says: *"Also asking oneself the right questions in your internal dialogue and also repeatedly going back to one basic question and also staying alert and conscious when addressing the link";* and in the same line UBA expert D 157: *"You have to concentrate and go over it again: Have you done it right? It was not as if you could do it without much brain power, but it worked. If you concentrate, it works quite well."*

230 For the difficulties of the UBA experts during the individual survey, see also an analysis of the comments they added to their matrices in Annex O.

231 *The difficulties* with the CIB logic of impact assessment in practice mentioned by the UBA experts have been *observed and reported on by the scenario experts too*. (V 33, with regard to the impact logic: *"Well, I think it was a bit difficult for some. I already noticed that In the initial feedback, I don't remember the exact details. So from the conversations, if you had the people at the workshop." Furthermore, some assessments collected during the survey did not make much sense and hinted at confusion*: *"I would also like to say, based on the feeling that some of the judgments seemed a bit nonsensical, I would say that many were a bit unsure how about how exactly to do it."* (ibid.). Scenario expert W observed difficulties with the direction of the impact assessment as well as with the assessment of direct impacts only during the individual survey and especially also during the expert workshop (W 138)and 215: *"What of course was constantly the problem, that things were meant indirectly. These indirect influential references. Personally, I also find it difficult. The UBA people have very often thought indirectly."*

232 Overall, the research team recognized that generally, *to understand CIB is not very easy for everybody* (e. g. interviews scenario expert V 33, and V 109). Scenario-expert V: 112: *"I think this is perceived as s an imposition by all disciplines."* Though, the 'imposition' is considered to be different one for different disciplines (cf. and in the following interview V 112—121). For natural scientists and engineers it is unusual and unfamiliar to give up mathematical precision and instead to qualitatively describe interrelations between qualitatively defined developments. For social scientists it is more unusual and unfamiliar to give up complexity and diversity and to reflect in fairly generalized terms.

stood by all.[233] For instance, during the ex-post interview, UBA expert F had forgotten the term 'consistent', but remembered the basic balance logic of CIB and was able to describe it rather correctly—even if not precisely:

> UBA expert F 122: *"So, at the end we had the scenario… it somehow fits with this, that and the other. Those were the results. The logical—no I don't think it was put quite like that—the most probable scenarios? No … […]"*
>
> HK: *"The most consistent."*
>
> Expert F 128*: "Oh yes, consistent. Well, I thought what came out at the end was good, where you can see, okay, when I assume this and that, then this, that and the other go together … and the fact that you still see how consistent it is and why it is not as consistent, and so on."*

Especially the analysis of the CIB matrix with the CIB software, which was carried out by the scenario-experts, remained a sort of **"***black box"* (cf. UBA expert C 44) to the UBA experts.[234]

At the same time there is evidence that the UBA experts trusted the effectiveness[235] and scientific soundness[236] of the CIB method, and that these were sufficient condition to accept the method's results, irrespective of how well the method itself was understood.[237]

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233 Some experts seem to have understood the general idea of the balance logic and its capacity to show why a selected scenario is internally consistent or not, as the following statement by UBA expert F indicates (F 128)*: "Well, I thought what came out at the end was good, where you can see, okay, if I assume this and that, then this, that and the other go together … and the fact that you still, see how consistent it is and why it is not as consistent."* On the other hand, there are some elements that speak against the interpretation that the consistency concept was understood by all. The scenario experts' experience with other CIB projects shows that to understand the consistency concept is not easy and that some people even never seem to fully understand it (cf. scenario-expert V, 109).

234 The analysis of the CIB matrix and the selection of scenarios clearly were not completely understood by all, as indicated by the reluctance of some participants to carry out the process themselves *"I would not dare to carry out this CIB over all process steps."* (E 36). *"Especially when it comes to consistency checks between the various factors and scenarios. That would be such a job. I would say I don't know whether it works if you muddle through it somehow all by yourself"* (E 39). This step was conducted mainly by the scenario experts with the help of a software program, ScenarioWizard, that the participants were not familiar with. See also UBA expert E 42: *„That was done by your institute; I have not tried it myself, and I do not know if this would work out without any problem."*

235 Cf., e. g., UBA expert C 41: "And I have not gone so deeply into the assessment. I have looked at how it was done, but was quite satisfied that it now clearly reduces the scenario space. In this respect it works. It was hoped of course that a couple [i.e. combinations] would be chosen."

236 UBA expert C 44: *"The assessment, well, to a certain extent, it is a black box until you start reinterpreting. I simply trust the fact that it works and because of the literature there is on it, there is also sound evidence to show that you can also take it with you in professional circles. And I find I like the fact that you can choose a method which is somehow well substantiated and also seems reasonable.";* And UBA expert B 99*: "I find it very plausible in any case. I have not doubted it."*

237 This perception is shared by the *scenario experts*. Expert V states he does not know how much effort the UBA experts have invested in understanding the consistency logic of CIB (scenario-expert V 86). And he has the impression that the general idea was understood (61): *"My impression I've taken with me is that it has basically arrived […]."* Furthermore, he states, too, that perhaps people do not have to understand the consistency principle fully to accept selected scenarios as plausible (V 61: *"[…]We still do not know whether anyone has actually understood this principle of consistency, found it convincing or whether it is simply enough for him to see, it is somehow made fairly meaningful and the results are plausible. I therefore also believe that the construction principle is sensible. That might also be the case and if anyone defines himself in such a way that he says that the results are plausible, I don't absolutely have to understand it in detail. Then that's also fine, and it's good enough for me*

From an external perspective, the editors of the *final report* at the Federal ministry of environment gave the feedback that the report is written in a very academic way and thus a text for specialists that is not easy to understand (Email 15.03.2012): *"Anyway, we find the report difficult to read and sometimes incomprehensible. The explanation of the methodological approach is too vague to have a really good understanding of the procedure [...] At the moment, it is a text for real specialists. […]."*

Factors influencing the understanding of CIB by (internal) actors were checked by "qualitative cross-tables" (Miles/ Huberman 1994), see e. g. Annex P. The comprehensibility assessment (self-ascribed) of CIB in the UBA case varies with the *prior experience* of participants with qualitative or quantitative scenario approaches and with the *continuity of participation* during the process. Actors with more prior experience and more continuous participation rate their own understanding of CIB better than those with less prior experience and less continuous participation. But, contrary to the experience reported by the scenario experts (e. g. V 109)—that generally, natural scientists and engineers have fewer difficulties with CIB than social scientists—the comprehensibility assessment in the UBA case does not vary in a clear pattern with the *disciplinary background* of the participants.

6.3.1.2 Scenario assumptions? [238]

Were scenario assumptions on future developments and on interrelations perceived as accessible and explicit during the scenario construction process and in the resulting CIB input data sets in the UBA case? Assumptions on *future developments* are seen as transparently described in numerical form within the input data sets and as well documented within the *descriptor briefs* (cf. e. g. scenario expert W 70, 141). Using CIB to construct numerical input data sets is assessed as a good tool to make scenario assumptions that underlie numerical modeling and simulation more explicit and transparent, as when UBA expert C (58) states: *"When such a matrix is used to show what goes into the particular model, then it is more transparent."*

In addition, UBA experts agree that *assumptions on interrelations* between developments weremade visible through the construction of the CIB-matrix.[239] If the hurdle of impact assessments (cf. above) is taken, the influence logic does uncover the mental models of those filling in the matrix, by making these accessible and explicit in the form of pair-wise interrelations, as for example UBA expert F turns it (F 154): *"I really found it a good way of working out what works with what and how and to clarify it."* And (F 140): *"[…]using this matrix, you really get to understand where the interactions are more intense and*

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as a methodologist. You don't have to force everyone involved. The goal is satisfaction. It is a heuristic instrument and therefore the goal is simply the need of those working with it to produce. "Now he has achieved plausible solutions." V 68: *"If someone does not deal with technical details and says, it will be reasonable."*

238 I have not asked the UBA experts directly on the issue of scenario assumptions, but within their general assessments of the UBA scenario process, its benefits and difficulties, there is some evidence in the interview material that is collected in this section.

239 Cf. e. g. UBA expert A, 44; D 151; F 140

where not so."[240] Some of the UBA experts also appreciate the fact that CIB goes beyond the logic of the classical consistency analysis (cf. interveiw UBA experts A and B).[241]

Furthermore, the pairwise assessment also allows for fresh thinking and new perspective on individual interrelations and to reveal normative and political bias in (implicit) assumptions. This was reported on with reference to the discussion of the influence of German CO_2 production on global climate change (cf. A 102, 105 and scenario expert W 216).[242] With regard to the documentation of these assumptions on interrelations, the CI matrix is assessed as being less accessible than the individual impact graphics. These are perceived as more attractive and traceable, because they visualize in detail the assumed impact for each descriptor and give verbal justifications for every impact judgment.[243]

As a limit to the explicitness of assumptions, the *scenario experts* consider the—only in part accessible but often implicit—assumptions behind pre-existing time series that have been, in a rather unquestioned way, taken over in this demonstrator process from the supply models (cf. e. g. FN Method questions: 55).

The internal UBA participants are, in sum, not overly optimistic that full traceability of scenario assumptions for *externals* is achievable with the given documentation in the form of the given report. Despite the documentation efforts, some experts doubt that anybody would invest the time to get that deep into the documentation. Others even think that *no external***,** who did not follow the discussion of the matrix, will understand everything by just looking at the results (matrix).[244]

In an application beyond the demonstrator, the use of the CIB matrix to manage sets of framework assumptions might increase the general need for traceability within a model group with regard to the

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240 See also UBA expert B during the final workshop, see FN Final presentation: 59.

241 E. g. during final workshop FN Final presentation: 51 ff.

242 During the cross-impact workshop, the discussion on the influence of German CO2 emissions on global climate change revealed that the agreed assumptions, that this impact is rather weak, is not a politically correct statement (see e. g. UBA expert A,99, 102-05 and scenario-expert W 216).

243 The overall *matrix* was perceived as practical but not very attractive or accessible. The matrix was assessed as rather "brittle" (spröde). UBA expert A 62 says: "*seems very brittle and therefore I do not think it is as intuitive, it's not as inspiring,"* looks rather like *(A 65) "Dots and Boxes"* (Käsekästchen). UBA expert A 65: *"If you look at the final documentation and then at these subnets, tackle visualization, the whole thing suddenly appears quite different. Then it opens your eyes again and your understanding of it. So if you can only see the figures in the matrix, my colleague thinks it looks like Dots and Boxes. It is not as recognizable as when you paint a picture next to it or have a picture, i.e. have a visualization next to it."* Furthermore, the matrix is judged to be *less traceable for externals* who did not follow the discussion than are the impact graphics of the individual factors (cf. expert A 65, scenario-expert V95, Expert A, FN Final presentation: 60*): "He said critically: If you are not involved in the discussion, the matrix is difficult to understand. The presentation of the various factors as in the report, on the other hand, is easy to understand."*

244 UBA expert A 121*: "Despite all documentation, that is even if I go now, no one, no outsider who has not been involved in the Cross Impact discussions, no one will understand the matrix, just by looking at it. That means you can accept it, you can say I believe you and therefore it is important that the group of experts that has created this matrix or the projects, has suitable standing."*

framework assumptions in use—and also with regard to assumed interrelations. The use of CIB then requires the models to uncover their assumptions (on inputs and on interrelations).[245]

6.3.1.3 Scenario composition and sampling?

Were the procedures of individual scenario composition and of the definition of the scenario sample perceived as traceable in the UBA case? Overall, the UBA experts experienced the construction of numerical sets of context assumptions with the help of the CIB method as very transparent. Still, most of these positive statements do not refer to the composition of individual scenarios and to the sampling with the help of the CIB algorithm alone, but also to the general procedures, the facilitation and organization of the demonstrator project. [246] The scenario experts were more cautious in their overall assessment of scenario process traceability than the UBA experts, but still positive.[247]

The *composition* of the *individual CIB scenarios* (input data sets) was considered traceable by the UBA experts and this was justified with the use of the (accepted) cross-impact balance algorithm (see above) and the cross-impact matrix. For instance, the matrix allows easily demonstrating, why a scenario is considered to be consistent or not, as expert B (66) put it: *"And the cross impact matrix itself, by the fact that you have, for example, always demonstrated the reasons why the assessments came about, that's obviously been very good for accountability."*

The traceability assessment is less positive with regard to the analysis of the CIB matrix with the help of ScenarioWizard and with regard to the resulting *scenario sample*. This step was carried out by the scenario experts alone—and remained in part a "*black box*" for the UBA participants (see 6.3.2.1 above), who were not using the software themselves and did not participating during the sampling either.[248]

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245 This then could be used to compare the consistency between different input data sets in use, as UBA expert C 58 remarked.

246 See e. g. interviews E 45, B 63, C 26, D 40-45, A 41, A 50). They were e. g. able to follow the process step by step (cf. E 45). Some perceived the entire process as traceable "always" (B 63) and "in all steps" (D 40-45).

247 The scenario experts assess the process as rather transparent (V 202 ff.), and that the opportunity was given to the participants to follow the process, as the following statement indicates: V 86: *"[…] Let's just say the offer was there […]. So I think based on the equipment and the offer, it* ***could*** *have been transparent. […]. And I think for many it was also transparent from the procedure."* The same actor presents the hypothesis that procedures have been transparent for those who *participated from the beginning*, e. g. starting at the at kick-off WS and working *continuously through the different process steps* (V 86: *"[…] So for the people who were also at this initial workshop from the outset, I think that at least the procedures have been transparent […]").*

248 See for example the interviews with the scenario experts C 44, 23 and E 39-42.

6.3.1.4 Summary traceability

In the UBA case, internal actors tend to perceive the traceability of the scenario construction process as given. [249] For a very short overview see Table 19.

Table 19: Summary of scenario traceability (UBA)

	Was the CIB method perceived as comprehensible? /was it understood?	Did scenario assumptions become accessible and explicit during the qualitative scenario construction process and in the resulting raw CIB scenarios?		Were procedures of scenario composition and selection of scenario sample transparent?
		On future developments	On interrelations	
Overall assessment	(+/-) CIB comprehensible but not easy: • Hurdle impact assessment. • Vague understanding of consistency logic. • ScenarioWizard remains a black box.	(+) Given.	(+/-) Given to internals. Only theoretically, through documentation in report, given to externals, too.	(+/-) Scenario composition for individual scenarios traceable. Software analysis of entire matrix and scenario sampling remains in part a (trusted) black box.

6.3.2 Interpretation: effects of CIB and of other factors of the methodology

In the following section, I propose an interpretation of degree to which the intended scenario traceability can be traced to first- and second-order effects of the CIB method, and what role other factors of the methodology as further methods, actors, data and conditions have played.

6.3.2.1 CIB

In sum, the CIB method characteristics show first-order effects on the traceability of the scenario (input data set) construction process of the UBA case. The use of the CIB supports the explicitness of the numerical assumptions of future developments, e. g. through their double, qualitative *and* numerical definition. The *impact logic* and the *formalized scale* of the CIB method have supporting impacts on the explicitness of scenario assumptions on interrelations. The traceability of the composition of individual input data sets (and of the sample selection) is supported by the systematic approach as well as by the consistency logic of CIB.

The application of the CIB software remained a black box to the scenario group and thus, traceability effects, especially with regard to the sampling of the input data sets were *hindered*—even if the results were trusted due to the scientific aura of the method.

The supporting effects of CIB on scenario traceability were not reached automatically and by CIB alone, but they were *supported* by other methods, actors and CIB generated data. Characteristics of

[249] The UBA case provides only limited evidence as to whether the process of constructing sets of framework assumptions with CIB is traceable for *externals*, too.

the methodology *hindering* scenario traceability were mainly linked to the social organization and to process conditions. This is elaborated in the following section.

6.3.2.2 Further methods (technical design)

The *facilitation* and *explication* of the method and the process by the scenario experts were important conditions to ensure that all participants understand the CIB method and apply it correctly and carefully. In contrast, during the rather unguided (and un-facilitated) impact assessment during the individual survey, the hurdle of the impact logic was not in all cases successfully surmounted. This led to technical uncertainty and in consequence to bias in the impact assessments (as the directions were confused and indirect impacts considered). During the joint *impact workshop*, intense facilitation effort was able to reveal and to correct parts of these (cf. also scenario expert W 98) as well as to identify issues of genuine expert dissent and political thought control (cf. scenario expert W 216). Facilitation played a major role in supporting the perception of process as traceable (cf., e. g., Interview UBA expert E 45).

6.3.2.3 Actors (social organization)

The scenario experts were active in the role of *trainers, facilitators* and *documenters* of the CIB process. Their efforts supported the understanding of the method by the UBA experts and thus increased traceability effects, e. g. with regard to assumptions on interrelations and with regard to the understanding of the composition of individual input data sets. Even if the incorrect application of the impact logic had led to bias within the matrix and hindered CIB's function to make mental models explicit—a rough or vague understanding of the consistency logic had no direct negative impact on the CIB process and might be sufficient for a rather passive participant, that is anyone who does not conduct the CIB analysis him- or herself.

The scenario experts were the central actors with regard to CIB analysis, especially with respect to the use of the scenario software and during the scenario sampling. The UBA experts were *not included in* these steps. This certainly lowered their perceived traceability of these steps and of the resulting input data sample. This social organization was chosen due to the limited resources and the demonstrator character of the project. Compensating for this lack of resources, the scenario experts' and UBA project management's strong *support* seems to have fostered scenario traceability, as it increased the effort people were ready to invest into explaining and learning and also their commitment and their engagement in contributing to a correct application.

Finally, the understanding of CIB and the perceived scenario traceability might have been further supported by the prior experience of the UBA experts with scenario methods. At the same time it might have been hindered by the (not always perfectly) continuous participation of UBA experts.

With regard to a full application, support and commitment to the approach could be a critical element if CIB is used as CIB&S within an entire numerical model group. Only then, the necessary co-operation and dialogue between different modeling groups could be ensured, allowing for the potential effect of making model assumptions more explicit.

6.3.2.4 Data (cognitive dimension)

CIB-generated data did support scenario traceability. The *CIB scenario table* fosters an overview of assumptions on future developments in different input data sets. In addition, the descriptor briefs, documented in the report, add the information on numerical input data representing assumed possible future developments with *qualitative* and *visual* definitions.

The CIB Matrix and especially the *individual impact graphics* certainly increased the traceability of assumptions on interrelations, and the graphics also more basically the understanding of CIB and its balance logic itself. This argument is shared by scenario expert V 95 and confirmed by UBA expert A (65):

> *"If you look at the final documentation and then at these subnets, tackle visualization, the whole thing suddenly appears quite different. Then it opens your eyes again and your understanding of it. So if you can only cf. figures in the matrix, my colleague thinks it looks like Dots and Boxes. It is not as recognizable as when you paint a picture next to it or have a picture, i.e. have a visualization next to it."*

The documentation of the process, and its results in the form of the *report,* seems to play a supporting role in the traceability of the process for external users and readers, more than for the internal users at UBA. Evidence suggests that internal actors rely more strongly on their own experience of the process. For externals, the documentation is recognized as being crucial but it remains an open question whether this report is sufficient to achieve scenario traceability for externals.

6.4 Scenario consistency: Assumptions and conditions

In the following section, I sum up what I learned from the UBA case on effects of the use of CIB within the specific scenario methodology on scenario consistency. Consistency effects are considered on two levels: First, with regard to the *internal consistency* of the individual scenarios and the consistency *within the sample* of numerical context scenarios (6.4.1). Second—and this time hypothetically—with regard to the potential effect of the use of CIB on the *consistency between framework assumptions of different models* of a group of models. The latter applies to the idea of a *full* CIB&S process, aiming at supporting the harmonization of the model group (6.4.2).[250] Note that due to the specific demonstrator character of the—in part only anticipated—CIB(&S) process of this case, the results

[250] Note that the level of 'consistency between' different types of scenarios does not apply here, as only one form of scenarios was constructed. This is analyzed in depth in the Lima Water case.

with regard to consistency are mainly on the level of ideas and reflection rather than on the level of empirical evidence.

6.4.1 Internal consistency and consistency within the sample of numerical context scenarios

In the UBA case, CIB and its consistency logic have been correctly[251] used to compose and select raw numerical CIB scenarios (or input data sets) (see section 6.1).Thus, following the consistency assumption A3, see 4.5.3), the resulting numerical raw CIB scenarios are *internally* consistent according to the (causal) consistency criterion of CIB. [252] The participants of the CIB process have stored their assumptions on interrelations between the developments of context indicators through the assessments of *pair-wise* impacts within the CIB matrix. The CIB balance algorithm then was used to consider all impact assessments, i.e. the *entire* impact network, and to draw conclusions (based on the balance sum of the ideas and judgments of the process participants on reciprocal impacts). As the sample of six types of numerical raw CIB scenarios or 'indicator scenarios Germany 2030' is based on one and the same CIB matrix, there is in addition consistency *within the scenario sample* according to the CIB consistency criterion. These effects of CIB are *assumed* and *not analyzed* in this study.[253]

Still, the question arises as to whether the process participants consider that these indicator-scenarios resulting from the CIB analysis make sense with regard to their overall mental models of future societal context developments. No systematic analysis has yet been performed on whether the formal consistency criterion of the CIB also matches with the more subjective sense of consistency of participants, see chapter 3. In the UBA case, the CIB consistency criterion and the resulting scenario sampling seem to have been accepted—even by those who did not fully understand CIB's consistency logic. One, there was no opposition or protest from the participants with regard to the resulting sets of context assumptions. Two, during the final presentation, an intuitively composed set of assumptions was tested with regard to its consistency with the CIB matrix, namely the combination of those variants being individually considered as the most probable ones. The consistency check with CIB showed that 4 out of the 10 variants in this constellation were inconsistent. This demonstration seemed to be accepted by the participants, too.[254] Potentially, the *scientific credibility* assigned

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[251] The application of CIB was correctly following the requirements of the method, i.e. the CIB method itself was fully applied.

[252] See assumptions and expectations in chapter 4.

[253] Still, such analysis would be possible e. g. by contrasting the CIB consistency criterion with other consistency criteria.

[254] Several open questions remain with regard to this issue—e. g. whether some solutions of the impact network are perceived as more consistent with the intuitive consistency feeling of process participants than others that appear more counterintuitive. And in addition, we did not learn whether the different sets of

to the CIB method,[255] as well as the noncommittal *demonstrator character* of the results contributed to this effect.

Overall**,** the UBA case can be considered a proof of concept of a new use of CIB; namely to analyze the range of assumed scenario uncertainty of input data of different models, and to construct internally consistent numerical input data sets (indicator-scenarios) out of the different indicators and time series. These sets *could* (hypothetically) be used to compare or even further harmonize model assumptions within a model group (and thus also support the consistency between context assumptions within a model group).

6.4.2 Consistency between framework assumptions of a model group (*hypothetical)*

I will now briefly discuss what consistency effects could occur in the hypothetical CIB&S case, using CIB to bundle input data of a model group and to feed these bundles back to the model group. In such an application, the CIB constructed input data sets could be used to compare and to adapt input data sets of different client models or even of an entire model group of supply and client models. The use of CIB in that form could thus contribute to the harmonization of this model group and finally support the joint interpretation of model outputs across this model group.[256] Where there are strong links, the model group would then be linked through the use of a shared set of framework assumptions (internally consistent and consistent with each other). Where the links are weaker, the CIB framework sets would be used for (soft) comparison or orientation of the individual model's framework sets. Even the use of CIB without a strict need to adapt model input to the CIB set could still reveal potential inconsistencies or differences in model assumptions. The question is what effect this type of design could have on the consistency between framework assumptions of a model group? To ensure full consistency between framework assumptions of a model group through CIB, these assumptions would need to be considered from a larger perspective, namely considering the supply models, too; and also in a deeper perspective, namely considering assumptions on interrelations of the client-supply models, too:

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consistent solutions do, from the participants' perspective, adequately represent the range of possible and relevant futures.

255 The rather vague understanding by some was counterbalanced with a portion of trust in the *scientific credibility of the method* that makes them accept the results, i.e. the proposed scenarios (Cf. expert C: 44, B: 99,F: 128.
One participant reported that the *systematic* check for internal *consistency* increased his trust in the *reliability* of the framework assumptions. Expert E (60) reports: *"It was actually precisely this structured approach to gathering framework data that, by comparison, I didn't have for my long-term scenarios, and because of that I noticed it also gives me a lot more confidence in the reliability of framework data when I have the feeling it is systematically checked and consistent."*

256 Note that the (hypothetical!) aim of 'harmonization of input data' was not consensual among the UBA experts during the demonstrator project.

6.4.2.1 Consider consistency between the framework assumptions of the supply-models and the CIB network

First, in such a constellation, input data would be supplied by different models from inside and outside the model group (see t1 in Figure 21) and choices on the data sources and the range (future uncertainty) to be included in the CIB need to be made, as already in the UBA case. The variance of time series for identical indicators results either from different model logic and/or, from different model assumptions, namely also from the diverging input data the supplier models themselves are based on. In a non-demonstrator project using CIB&S, one would need to ensure that the framework assumptions underlying the information that is provided by the supplier models are consistent with the information that is fed into the CIB. Access to the (not always explicit and transparent) assumptions underlying these input data is necessary to allow comparing and assessing it thoroughly.

6.4.2.2 Consider consistency between the interrelations assumed by the client models'and the CIB network

Second, the client-models (see t3 in Figure 21) might use some of the information provided by the CIB as exogenous parameter (model input)—but some of them also might endogenously calculate some of the indicators that are (also) provided by the CIB sets—since they are needed as model input by other models. To avoid inconsistencies between the assumptions on interrelations, leading to these indicators calculated by the model and to the time series sets provided by CIB, the (pre-existing) client model would then need to be considered as a supplier model first. In this function, the model would deliver information on interrelations between descriptors to the CIB that could be taken over into the matrix in a semi-qualitative form. These parts of the matrix would then not require additional expert assessment.[257] We *would then be dealing with consistency issues on the level of the underlying models, by linking CIB and the numerical models on the level of internal model structures.*

Overall, the use of CIB to manage consistency between context assumptions of client and supply models requires dealing with a certain level of complexity. This complexity requires answers to questions regarding the social, cognitive and technical aspects of such a methodology.

6.4.3 Summary consistency

In sum, in the UBA case, CIB has proven its triple potential—first, to analyze the range of (that is the future uncertainty within) the framework assumptions of a model group; second, to analyze the interrelations between (that is the complexity of) the framework assumptions of a group of models;

[257] If several models inform the CIB on the same interrelation and if CIB gets diverging information by the different supplier models, then CIB can test the consequences of the different assumptions on the scenario sets.

and third, to generate samples of internally consistent sets of numerical framework assumptions out of (pre-defined) indicators and time series, see Table 20.

In an application beyond this demonstrator case, these sets could be used to compare, adapt and potentially even harmonize the framework assumptions of a model group. This application would then require considering supply models and client-supply models and their assumptions (on inputs and on interrelations) more thoroughly (i.e. considering the consistency of underlying models, too).

Table 20: Summary of scenario consistency (criterion: CIB) (UBA)

	Scenario consistency			
	Internal	**Within**	**Between**	
			Level I: Input data sets of different models	**Level II: Underlying models**
Overall as-sessme nt	Internal consistency of individual sets of framework assumptions following the CIB cri-terion as-sumed.	Consistency within sam-ple as-sumed, as all sets are internally consistent solutions of the same CIB impact network.	Missing precondition: Time series provided to CIB by supplier models is also based on (often implicit and not transparent) framework assumptions, *A non-demonstrator appli-cation of CIB&S would have required accessing those to ensure consistency between those,* *If, hypothetically, CIB based input data sets are used by different client models, their input data sets are con-sistent with each other (see consistency within).*	*Conceptual CIB vs. num. model(s): Hypothetically, consistency between the interrelations assumed by the client models and the CIB network: In a full CIB&S process, every client mod-el that has endogenized one or more of the CIB indicator-descriptors could serve a) as a supply model to the en-tire model group and b) to the CIB network by providing (semi-qualitative) information on its as-sumptions on interrelations between indicator-descriptors.* *These could be included in the CI-matrix (to avoid mismatches between additional-expert guess -based CIB assumptions and model assumptions on interrelations).*

6.5 Other (unintended) effects

In the following section, I group evidence for other effects of the use of CIB within the scenario methodology of the UBA case into four aspects: First, the use of CIB in combination with numerical models challenges—and is itself challenged by—current model practice (6.5.1). Second, the effort of using CIB is rather high and attempts to reduce this effort do increase the risk of bias (6.5.2). Third, using CIB in the UBA case design did not open much room to scenario creativity (6.5.3). Finally, pertaining to the hypothetic full form of application of CIB&S, questions arise concerning the flexibility and adaptability of CIB-managed frameworks for model groups (6.5.4).

6.5.1 CIB in tension with current modeling practice

In the *UBA* case, the application of the (originally *qualitative*) CIB was confronted with the current modeling practice and the *numerical (model-based) scenario culture*. This model based scenario culture is characterized by scenario building based on quantitative information and available data.[258] It is current practice to use certain indicators;[259] and to use conventional assumptions on future developments from high credible sources, which also cover a predefined range of future uncertainty. This classical practice of framework data selection (cf. e. g. UBA expert A 18) was challenged by the new CIB approach, as it introduces different ideas on qualitative scenario processes into the methodology. For instance, it does so by opening the range of future variance beyond the one that is classically used by the individual models.[260] In sum, in this case, this tension was mitigated by the specific design and character of this particular CIB analysis, which was a numerical, data- and modeling -practice driven CIB design.

In addition, especially with regard to an effective use of CIB for harmonization purposes, important opposition from the modelers was expected. By the way, this opposition was expected against every effort of harmonization, no matter what the method used for this purpose. Basically, the aim of harmonization of framework assumptions is not unanimous at UBA. Actors repeatedly argued that specific models need specific assumptions, and that a common set of framework assumptions could never optimally fit individual models. The introduction of CIB challenges the power of the individual modeling groups. These would no longer be completely free to use their ideas on the future of social contexts, or to use the input data that suit their models or model results best. In addition, important organizational obstacles against a harmonization of framework data through the use of CIB generated sets were seen at UBA.[261]

6.5.2 If you try to save some of the new CIB effort, you risk different types of bias

UBA case participants considered that—compared with modeling only approaches—using the systematic CIB approach substantially increases the *effort* that is required to construct context scenarios

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258 Reconsider the example of the use of the indicator, *total material requirement* (TMR), for which data availability has primed the descriptor-indicator selection.

259 Reconsider the example of the indicator *GDP* for which the current modeling practice has primed the descriptor- indicator selection.

260 For instance, the variance of one of the standard input indicators *population growth* now is far larger than the range that is usually assumed by model based scenario studies, as scenario-expert W (55) pointed out. He fears that the resulting scenarios could be too extreme and not matching the current scenario ideas that most modelers are working with. (cf. also W 55 and W 172, W 174: *"It's done like this [with the factor demography] everywhere. There are two middle paths that are taken in every case. And we had a path like that in the middle that effectively appears nowhere." And probably only that one is consistent with all the others because the idea that we are heading towards the 100 million is nonsense. The idea that we are going down to 60 million is also nonsense. This means we would have to do a bit more fine tuning.")*

261 Harmonization of framework data would require some form of (willingness for) coordination: It is unclear how, at the moment, such a process could be organized at UBA within the existing structures of rather independently working model groups, that, in addition, often cooperate with external consultants. Neither a top-down approach by the leading UBA management dictating the CIB&S approach nor a discursive bottom-up process, integrating all modeling teams, is seen as being realistic at the moment (see e. g. FN Final presentation: 84 and interview UBA expert C 61).

or input data sets.[262] Furthermore, there was evidence that, if actors try to *save* some of this effort, this results in different forms of *biases,* namely biases within the CIB matrix and thus in the resulting scenarios and input data sets. First, when the impact assessment is not fully understood and not correctly applied (e. g. if the direction is reversed or if indirect impacts are coded), it can result in biased impact assessments (see 6.3 above). Second, if interrelations are only considered superficially, only already known interrelations are considered, and other potentially relevant ones remain unrevealed.[263] Third, reworking or correcting parts of the assessments might require further adaptation and corrections of *other* parts of the matrix, too. If, as in the UBA case, only *some* of the judgment groups are adjusted, other related parts of the matrix might be biased. Thus, the impact assessment needs to be carried out with the same effort for all impact groups and by pondering the weights of impact across the entire matrix to avoid this.[264]

Fourth, when using CIB, a *standardization* convention is recommended, which balances the impact assessments within one judgment group to “0” (see 3.1.1.1). Matrices in which this rule was applied consist, in sum, of an equal number of promoting and hindering impact points, and the overall matrix sum is 0. Due to the experience in other CIB processes, in which many people seemed to have difficulties with this convention, this rule was disregarded during the UBA process. This simplification might have made the task of using the 7-point scale for deciding on inhibiting and promoting influences *easier* for the UBA experts. But it seems that omitting the standardization convention at the same time had *unintended effects*: First, it might have led to more superficial and fewer intense considerations of the individual judgment groups, as scenario expert W (86-87) suggests.[265] Second, leaving out the standardization clearly allowed users to emphasize promoting impacts between developments and to overlook hindering ones: The (mean and final) matrices clearly show an overweight of promoting (positive) impact judgments: [266] In the mean matrix, 75% of all (non-zero) judgments are assessed as fostering and only 25 % as limiting impacts; the overall matrix sum is ‘+ 171’. In the final matrix Germany 2030, the imbalance is a little smaller, of all (non-zero) judgments, 64% are assessed as promoting, 36% as limiting, the overall matrix sum still is ‘+87’. The joint workshop thus

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262 The effort of a CIB has been assessed as rather high by all UBA experts (see interviews A 50, B99, C 23, D 48, E 29, F 34) - but worth it (see interviews A 59, B60, C 47, D 87, d 87 and 164, F 86, A 59).

263 UBA expert F 74: *“I can imagine that that you ... that wherever you have preconceptions, you can then say, no, that doesn’t fit and you then don’t give it any more thought. Naturally, that might then also be the case if you are up against a big matrix. Then you still consciously tackle the interactions that you had in mind.”*

264 Cf. scenario-expert W 98 and W 105: *“And the joke is that then, for example, perhaps something was cleared up or a discrepancy was resolved, as a result of addressing this one factor. And not gone through this with another factor. And I always had the feeling that if we worked even more systematically at the other, we would again have revised all the judgments.”*

265 Scenario-expert *W 87: “And then I thought “Oh my God, they have not aligned it at all [i.e. had not applied the standardization rule]– when I saw the results. I was disappointed when I saw the matrices [of the individual survey]. Because I thought not very much work had been done with it.”*

266 For a detailed analysis of the matrices see Annex N.

countered this bias towards fostering-impacts, but did not fully reduce it. Furthermore, through the joint discussion in the workshop, the overall number of impacts assumed by the individual experts was reduced (from 453 to 529 '0 impact- cells', containing mainly slightly promoting impacts (+1) into no impact (0) assessments). In the UBA case, filling the matrix individually resulted in impact networks with a higher interrelatedness than could be justified during the workshop.

6.5.3 Not much room for scenario creativity

In the UBA case, the room for scenario creativity was perceived as small. Actors stated that scenario approaches do need systematic analysis but that they also require creative elements (cf. e. g. A 121), and that the systematic CIB approach in its specific numerical and model driven form of application was perceived by some as rather hindering creativity (cf. e. g. experts W 239, B 124).[267] To what degree this effect needs to be attributed to the CIB itself or to this specific numerical and model-driven application, which also left very little room for an open definition of the scenario space or the inclusion of qualitative scenario elements, is further discussed in the final section of this chapter (see 6.6.3).

6.5.4 How flexible are CIB-managed model frameworks?

Overall, in the (effective) UBA case, questions were raised about how a CIB&S methodology beyond the demonstrator application could ensure the flexibility and adaptability of framework sets over time.

In a full CIB&S application (Type UBA) such flexibility and adaptation might be required at two moments. First, when a model group starts to harmonize its framework assumptions, feedback loops and iterations between client models, supplier models and the CIB impact network might be required to adapt otherwise non-matching assumptions. This is especially expected in client-supply model constellations, when models supplying information to the CIB are at the same time exogenously driven and are clients of the new CIB generated input data sets –and the use of these input has an impact on their CIB- relevant results (see also 6.4.2).

Second, later during the process, it might be necessary to react to new systems and future perceptions and projections that are developed over time and that change the range of futures taken into account. These would need to be integrated into the CIB and into the client model simulations. How to synchronize diverging model cycles with readymade context scenarios was seen as an open chal-

[267] Scenario-expert W 293**:** "Creativity has stalled repeatedly in the process." and UBA expert B: 124: "[…] In this respect, I think it's more about things such as whether you're happy working systematically or whether you feel that this hampers you."

lenge by the UBA experts, too (e. g .UBA expert C 61).[268] *Using an additional conceptual CIB model could even hinder a flexible adaptation of input data sets over time, to avoid the effort that is required for adapting the CIB analysis. Therefore, procedures to reduce the risk of sticking to old data in fear of new harmonization efforts need to be clarified in such constellations. Possibly, a good understanding by all model groups, not only of the input data sets but also of their underlying interrelations, could help the model groups to find solutions in an educated and careful way to bridge the time until the next overall harmonization round—without renouncing the flexibility of using newest data.*

6.6 Synthesis: Findings from the case study UBA

In this section, I sum up the findings from this case by answering the three research questions specified for the UBA case (see section 5.2.4). First, I briefly sum up the form and function in which CIB was used in the UBA case (6.6.1). Second, I summarize first- and second-order effects of CIB (6.6.2). Third, I discuss the degree to which these effects have been influenced by other factors of the methodology and especially the form of combination (6.6.3). Finally, I summarize central insights from this case (7.6.4). Overall, I focus on the effectively realized demonstrator application but add some key thoughts concerning the anticipated full application.

6.6.1 Form and function of CIB

The first question in the UBA case referred to the form of combination: In the UBA case, CIB was applied within a demonstrator project under restricted resources. The two central aims of the application were to realize a proof of concept and to establish CIB method competence at UBA. CIB was applied to analyze, compare and bundle numerical input data (indicators and time series) currently used by (mathematical) environmental modeling and model-based scenario studies at (and commissioned by) the UBA.

In this brief and numerical application of CIB, the CIB represents model contexts through numerically defined indicator developments (system representation). The CIB takes over input indicators and time series used by the client models, which are explicitly and implicitly provided by supplier and client-supplier models (soft link). With regard to the position, models are structuring the CIB scenarios scope and content, thus CIB is a service provider to the model group to (re)consider and (newly) structure these contents (models first).

This application was considered a successful proof of the concept that CIB can be used as a manager of the framework assumptions for a group of models. In the UBA case, numerical information on

[268] See e. g. UBA expert C 61: *"The projects never run all in synch, but at different times and then there is a follow-up project and that's when the results are compared with the previous one. Then you actually have to commit to it [to the method] and persevere for a couple of years and in all affected units."*

model contexts (i.e. scenario content) is provided by the numerical models; CIB is used to structure the information into meaningful sets. This is done through the qualitative assessment of interdependencies between individual input data factors. Numerical data is *qualitatively* reinterpreted in the form of a conceptual model of the societal contexts of the numerical models.

In an anticipated full application, the form of combination could look slightly different: The input data sets generated by CIB would then be fed back to the models (link) and used either to compare or even to adapt the numerical model input. In the latter case, deeper integration between CIB and the numerical models including mutual comparison and adaptation not only of assumptions on future developments but also of internal model structures (interrelations) might be required. [269]

6.6.2 Effects of CIB

The second research question of the UBA case referred to outcomes concerning scenario *traceability* (6.6.2.1), scenario *consistency* (6.6.2.2) and other effects (6.6.2.3). This section focuses on the first-order effects of the method's core of CIB and the second-order effects of CIB. Effects are considered second-order or indirect effects when they exert their influence on scenario process or products through CIB-generated data or through actors promoting CIB. CIB effects are considered contingent when their realization depends on certain conditions. Other factors of the methodology that impact the process and products (rather) independently from CIB are summed up in the subsequent section (6.6.3).[270]

6.6.2.1 Effects on scenario traceability

The UBA case has shown that understanding CIB is a precondition to perceived scenario traceability in a CIB(&S) design. CIB was overall assessed as *comprehensible*, but not unchallenging. The comprehensibility of CIB was directly influenced by the different characteristics of CIB: The systematic approach is easy to understand in principle but demanding in practice through the repetitive character of the exercise. The CIB impact logic was a hurdle the UBA experts had to jump for a correct application of the method. The formalized impact scale was judged as easy; but the consistency logic were not that easy to understand, and most of the UBA experts developed a vague understanding only. The application of the CIB software remained a black box to most UBA experts which was hindering the method's comprehensibility as well as its traceability effects. Through CIB generated data and through actors, CIB had second-order effects regarding its own *comprehensibility*. Especially the im-

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[269] *In a full application, CIB could also take over information about interrelations between descriptors, if a model has endogenized these). CIB produced input data sets could (but this step is only anticipated) be linked in a soft way to compare them with a client models inputs, or in a hard way when the client model actually uses them as framework data.*

[270] This division is an analytical one, as there is an interplay of different sorts of effects of CIB and of other elements leading to specific phenomena.

pact diagrams made it easier to understand the balance logic of CIB; and the scenario experts, in their role as CIB trainers and facilitators, fostered the qualified application of the approach.

The *traceability of assumptions on future developments* was assessed as given, *the traceability of interrelations* was perceived as given to internals and only theoretically, through the documentation in the report, to externals, too. This was directly supported by the systematic character of the CIB, explicitly listing indicator-descriptors and time series-variants and forcing participants to (re-)consider pair-wise interrelations, even those that had not been thought of before. The CIB impact logic supported making mental models on interrelations explicit and the formalized impact scale led to (comparable) characterizations of the intensities of the assumed interrelations. In addition to these first-order effects, CIB-generated data and CIB actors had supporting impacts, too: Assumptions on future developments are stored in the scenario table and matrix, which also documents assumptions on interrelations in a short and semi-formalized format. The impact diagrams fostered their accessibility through visual and verbal representation. The scenario experts fostered access to and explicitness of assumption on interrelations through training, explication and facilitation, especially during the joint impact assessment workshop, by repeatedly asking: "Please consider this impact assessment again." (cf. interview expert W).

The *composition of individual scenarios* was perceived as traceable by the UBA experts, the software analysis of entire matrix and *scenario sampling* was not fully transparent—but trusted. CIB had a first order effect on this dimension of traceability, as its systematic approach and balance logic make the composition and selection of scenarios traceable, at least for those who fully understand it. In addition, its software-supported balance algorithm ensures a systematic and comprehensive consideration of all theoretically possible interrelations. But in this case, the *application* of the software remained a black box to the scenario group. The scenario experts, with their expertise in the method, were alone responsible for the CIB, carrying out the analysis of the matrix and the sampling. This hindered the traceability of scenario construction and of sampling for the UBA experts who nevertheless trusted it due to the scientific aura and credibility of the method. Furthermore, CIB had second-order effects through the scenario table, allowing easy access to the sample.

6.6.2.2 Effects on scenario consistency

The *internal consistency* of input data sets as well as the *consistency within the input data sample*—according to CIB—was ensured by the application of the CIB balance algorithm. This is a first order effect of CIB, as the adequate application of CIB, including its systematic character and its specific impact logic, was ensured through the CIB 'advocates', the scenario experts.

Whether CIB results also meet the participants' intuitive feeling for consistency cannot be empirically proven—but there are hints that the CIB consistency criterion was accepted. This acceptance was potentially supported by CIB's scientific credibility and the noncommittal character of results of the demonstrator application.

Considering the hypothetical full application of CIB within a model group, CIB-produced data—the input data sets—could be used to support consistency between the different input assumptions of the different models of the model group. This would be a second-order effect of CIB on the level of scenarios. Furthermore, the systematic character of CIB and the traceability of assumptions on future developments and on interrelations could be a precondition for model comparisons, which in turn are preconditions for model adaptations that could support consistency between the conceptual CIB model and the numerical supply and client models. This would be a second-order effect of CIB on the level of model structures.

6.6.2.3 Effects on further phenomena

In the UBA case, the application of CIB had further (unintended) first- and second-order effects. First, the main function of CIB is to support the decision about scenario and sample structures, and in this case to propose input data sets. This role clashes somewhat with current modelling practice, in which each model group is able to decide about their input data autonomously. Second, applying CIB requires effort in terms of time and method skills. Attempts to save some of this effort, pose the risk of bias. For instance, omitting the standardization convention led to a CIB Matrix with a clear bias for positive impacts. Third, the systematic and formalized characteristics of CIB prime the character of the scenario process and of the scenarios. The specific CIB impact logic requires to simplify ones assumptions on interrelations—and does not especially open up room for detail and creativity. Finally, questions were raised as to how a CIB&S methodology (beyond the demonstrator application) can ensure the flexibility and adaptability of its framework sets over time, comprising also the adaptation of the CIB matrix over time. Finding adequate solutions might require considerable expertise in the CIB method.

The contingent and second-order effects of CIB presented in this section are linked to the broader methodology of the UBA case. Therefore, in the final section, I will present the factors that have contributed to the effects that, until now, have been attributed to CIB alone.

6.6.3 Role of other factors

The third research question of the UBA case referred to factors influencing these effects, namely to the influence of the characteristics of the specific UBA methodology (6.6.3.1) and to the specific form in which CIB was combined with numerical simulation models (6.6.3.2).

6.6.3.1 Characteristics of the methodology

Social organization and technical design

In the UBA case, the social organization of the methodology and, to a lesser degree the technical design, influenced and contributed to effects of CIB. Especially with regard to scenario traceability, CIB trainers and facilitators with high method expertise supported the correct application of CIB and reduced bias,[271] especially during the joint cross-impact workshop, during which dissent between the individually filled matrixes was discussed. This facilitation and explication was a precondition for comprehensibility and, in the end, for the traceability of participants' mental maps stored within the interrelations of the CIB matrix.

At the same time, the scenario experts alone were responsible for the analysis of the matrix and for the sampling of input data sets. An inclusion of the scenario group in the analysis of the matrix and the sampling was not possible under the restricted project resources. This might have hindered a better understanding of the CIB software and a higher traceability of scenario construction and sampling for these actors. Along the same lines, the non-continuous participation of UBA experts hindered their individually perceived comprehension of CIB—which was at the same time supported by their prior experience with scenario approaches. Furthermore, in the UBA methodology, models were supplying scenario content and no explicit creativity method or technique was used. In consequence, the systematic, numerical and pre-defined character of this particular CIB dominated the scenario content and structure—which left not much room for creativity.

In a full application, the users need to find a social design and technical organization that generally allows dealing with the potential clash of scenario cultures, and that more specifically support the comparisons and potential adaptations of model structures, to support traceability and consistency effects (matching part II).

Cognitive dimension (data used, processed, produced)

The cognitive dimension of the methodology has influenced the character of the CIB scenarios: The use of pre-defined and numerical D&V, provided by numerical models, framed the CIB scenario content (see the effects of system representation below, too). The implicit assumptions underlying this data were not made explicit within the framework of this short demonstrator project. CIB generated products as the scenario table and impact diagrams had fostering impacts on scenario traceability already described above. These products were included in the report in an attempt to support traceability also for external users. This report also contains the descriptor briefs that (re-)consider the individual input data in textual, numerical and graphical form. Thus, they support the traceability and

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271 Bias occurred for instance in the form of technical uncertainties concerning the impact logic as well as through the 'positive-impact bias', induced by leaving out the standardization convention.

accessibility of assumptions on future development beyond short qualitative and numerical definitions provided by the matrix and the time series respectively.

6.6.3.2 Form

System representation

In the UBA case, CIB represents model context by combining numerically defined indicator developments as descriptors and variants. This specific representation of the system is due to the specific function of CIB in this case and results in a very quantitative form of CIB. In this form, future developments are defined in a numerically precise way but with less qualitative depth, for instance by leaving out qualitative, intermediary variables, as the scenario experts themselves noticed:

> *So from the scenario perspective, I find that the rather soft factors are still lacking. The fact that we have confined ourselves to making only framework assumptions for models without explaining things, that have been virtually put across, I now find them incomplete. For the limited space in which they were created, they are successful, relatively meaningful, but only with this restriction.* (Interview scenario expert V 133)

As the scenario content is pre-defined by models' needs and requirements, data availability had a strong influence on the scope of the CIB analysis, such as on the *time horizon* chosen, on the *selection of indicators over others,* and through the *choice of variants* also on the range of possible futures that was taken into account.[272] Overall, this data-driven approach left little room for creativity (independently from the scenario method that was used!) and no room for rethinking the possible future range of developments.

> *Unfortunately,the method was limited in this application, because we have also confined ourselves to a rather quantitative logic ("high," "medium ,"" low"). It could be much more interesting if you start from real descriptions and qualitative considerations. If you would rather have chosen a softer scenario approach, you would certainly have covered a broader area for future developments.* (Interview UBA expert A 96)

Through this form of system representation by CIB, no translation of qualitative data into numerical data is necessary. In consequence, the *effort* seems to be reduced in this form of application. However, the indicators and time series still do need *some* form of qualitative (re)interpretation, which in this specific methodology was done through the descriptor essays and the discussion of interrelations during workshops.

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272 The range of possible futures taken into account was not open to discussion and there are several hints that this was perceived by the UBA experts as too narrow. Their need to represent higher levels of 'future uncertainty' lead to the decision to choose extreme over conservative time series, to formulate the fourth variant of GDP (*not* based on a prior study *and* formulated *qualitatively*) and to introduce wild-card analysis to cover more extreme developments.

Position

This specific representation of the system by CIB is also due to the models first approach.[273] The CIB scenarios do not define their own scope but are completely subordinated to the models' input. This somehow creates tension with the classical task of CIB as a qualitative scenario approach. Still, the position of CIB does not seem to have an impact either on scenario traceability or on scenario consistency in the UBA case.

Still, in the anticipated full application, the position of CIB might have an effect on the issue of flexibility: In case of adaptations, it has to be made clear whether the CIB or the CIB generated input sets vs. the numerical models are considered the benchmarks.

Link

CIB takes over input indicators- and time series used by the client models. This f*ront-end coupling* with the supply models lead to the (unquestioned) takeover of (at times implicit and in transparent) so to say '*assumptions behind assumptions'* and thus touches upon questions of scenario traceability.

In a full application, the CIB-generated input data sets would be fed back to the models. This link could have effects on scenario traceability and consistency, depending on its form as a hard or soft link and depending from the level of link: A link on the level of scenarios could support consistency between input data sets of different models. A link on the level of model structures would require comparing model structures (with a traceability effect) and potentially even adapt internal model structures through a form of matching part II (with an effect on consistency of underlying models).

6.6.4 Central insights

First of all, there a two reasons to be especially cautious when drawing conclusions from the UBA case. For one thing, the case was a method demonstrator, during which method interest prevailed over other considerations that might become relevant in practice. For another, the full application was only hypothetical. Therefore, additional methodological issues linked to this specific form of CIB&S might occur that we are not aware of yet, as parts of this application constituted a thought experiment.

Still, the central insights one can draw from the UBA case are that for scenario traceability, using CIB helps, but it is not enough. Instead, a suitable social organization and technical design as well as appropriate data management and documentation are important factors. With regard to internal scenario consistency, CIB is effective. Still, with regard to consistency between scenarios (here input data sets) and between underlying models, the *link* between CIB and models plays a crucial role. And certainly, this link has to be organized on the social, technical and cognitive level, too. In this case,

273 In this case, it seems that the system representation is not independent of the position.

the system representation by the CIB seems to be critical with regard to the numerical and not overly creative character of the scenarios—more than CIB as a method itself.

Finally, flexibility of an input data set managed by CIB might be a question of social and technical organization of such a full application, potentially supported by sufficient resources in time and expertise in the method, and the form of matching on level II.

This full application of CIB&S—without brackets—still has to be tested empirically. But the UBA case already shows a way toward input data of higher quality, which are shared by a group of models and managed through a joint use of CIB.

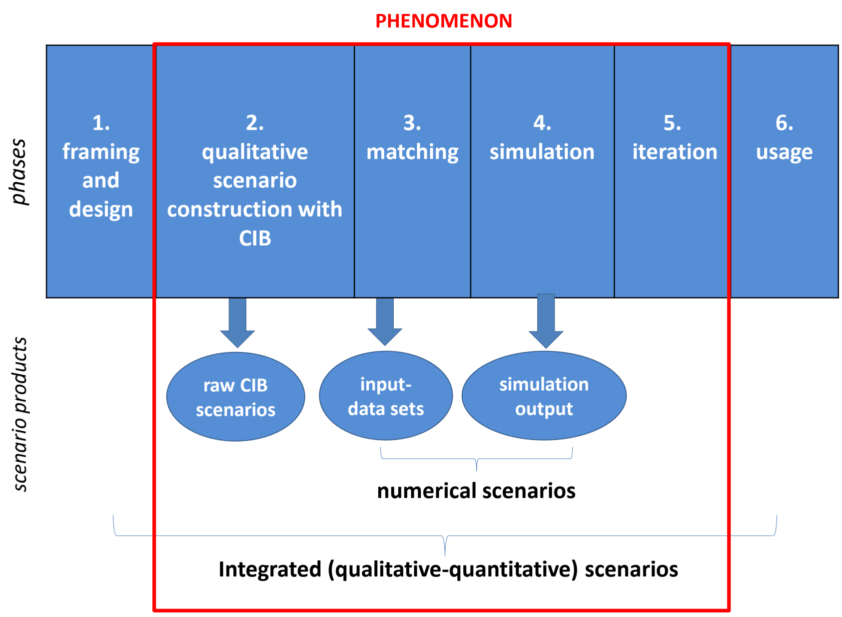
Chapter 7: Results from the Lima Water case

In this chapter, I present selected results from the analysis of the Lima Water case. For the guiding questions of this case, its selection and design, see Chapter 5. First, I describe the specific scenario methodology of the Lima Water case (7.1) and second, I focus on the form in which CIB was combined with the numerical water infrastructure simulation model LiWatool (7.2). Third, I assess effects of the use of CIB within the specific combined scenario methodology of the Lima Water case on scenario traceability (7.3) and scenario consistency (7.4) step by step through the different phases of the integrated scenario process and interpret their logic. Moreover, I present evidence on other effects (7.5). Finally, I synthesize central insights and interpret, how the effects in the Lima Water case are influenced by the CIB method itself, by other characteristics of the specific Lima Water scenario methodology and by the specific form in which CIB was combined with LiWatool (7.6).

7.1 The CIB&S methodology of the pioneer application

In the Lima Water case, a *pioneer application* of a full CIB &S process was realized within the Megacity project LiWa. Figure 22 shows that all phases of an ideal type CIB&S process were covered in the Lima Water case. These phases are marked in blue; the red frame delimits the phenomenon under study.

Figure 22: The phenomenon: CIB&S process steps and products covered by the scenario process (Lima Water)



To allow the reader to follow the later analysis and interpretation of the case, I describe its methodology.[274] First, I give a short overview of the entire methodology of the case (7.1.1.); then I summaryze its immediate context (7.1.2) and present the scenario process in more detail by zooming into the different phases (7.1.3—7.1.7). Finally, I characterize the overall methodology with respect to its social, technical and cognitive organization (7.1.8).

7.1.1 Overview

7.1.1.1 In a nutshell

In the Lima Water case, with the aim of constructing exploratory scenarios of Lima's Water futures 2040, the CIB method was used by a local scenario group to construct *raw CIB scenarios*, facilitated by the ZIRIUS scenario experts. In parallel, these qualitative scenarios were further elaborated into *storylines* by the scenario experts and the scenario group, and were translated jointly by modelers and scenario experts into numerical *input data sets* (first half of numerical scenarios) to inform the newly built water infrastructure simulation model LiWatool. Afterwards, simulation generated numerical *output* (second half of the numerical scenarios). Finally, scenario experts and modelers combined these numerical scenarios with the storylines into *integrated scenarios* of Lima's water futures 2040 and published them in the form of a scenario brochure.

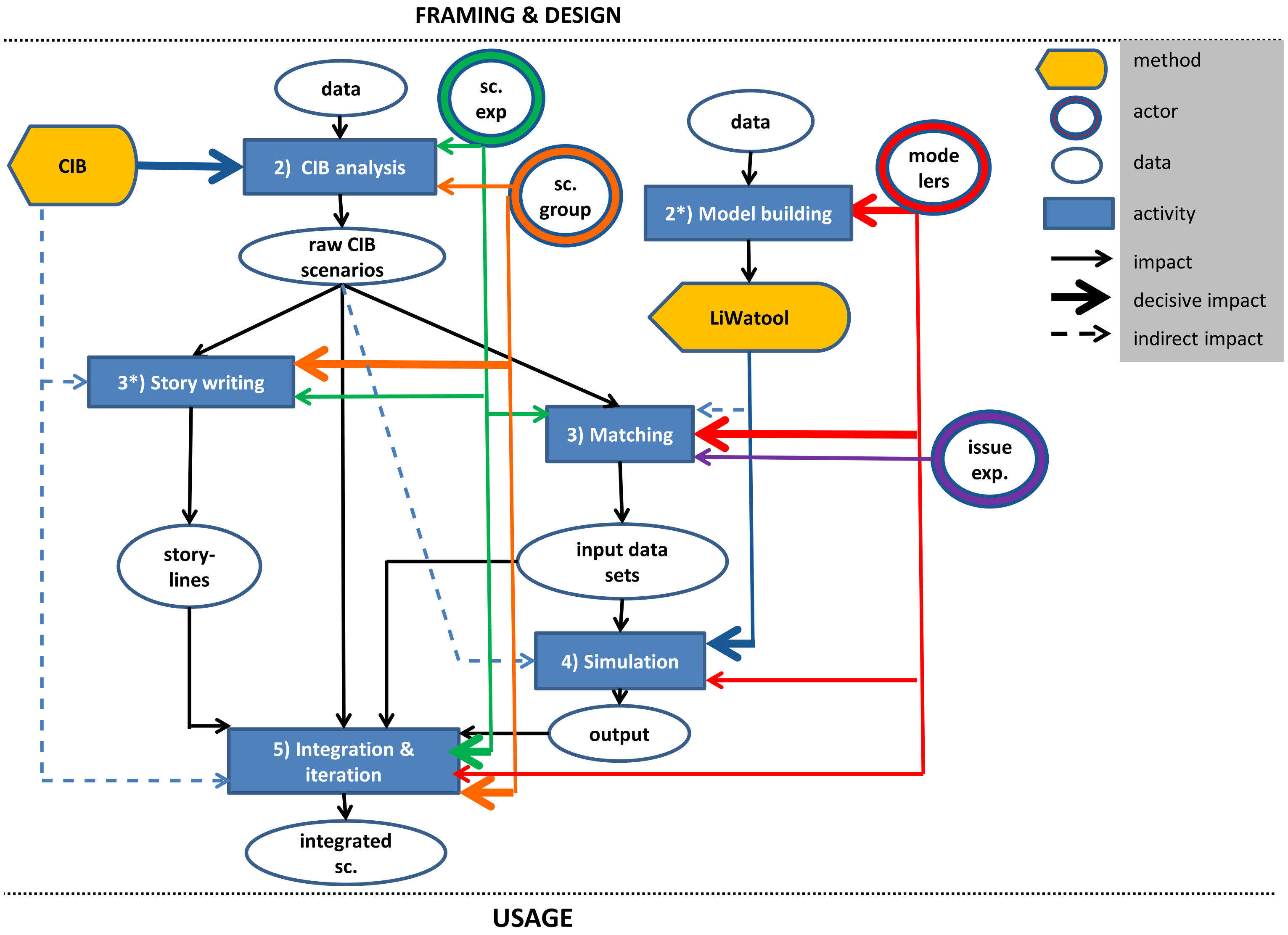
7.1.1.2 In one picture

Figure 23 gives an overview of the central phases of the scenario process and a very simplified overview of the constellations of central actors, methods and data along these phases. A few words about these actors are necessary before going into the description of the process. The central *internal* actors of the Lima Water case were *modelers*, *CIB scenario experts* and the *scenario group*.[275] Modelers (three internal and two external ones) in Germany worked on the model building of LiWatool and the simulation, among them, the overall coordinator of the LiWa project. CIB scenario experts (four, with two or three working constantly on the project), including the project manager in Peru, facilitated the qualitative scenario construction, the matching and the construction of combined results. I belonged to this group and, in addition, had the role of the 'combination-person'.

[274] This description is mainly based on participant observation and process documents and was validated by two key informants, see chapter 5.

[275] Further actors from inside and outside the LiWa project are '*side actors'* in the CIB&S process, in the role of *issue experts* (German researchers, Peruvian project partners, external local experts and stakeholders). They supplied issue expertise, external comments etc. For more detail on the internal actors see Annex Q.

Figure 23: Visual summary of the CIB&S methodology, simplified overview (Lima Water)



Local Peruvian experts and stakeholders (seven to ten) from Lima, represented the Peruvian project partners, meaning mainly the water company SEDAPAL, several NGOs as well as the engineering university.[276] They formed a scenario group working on the qualitative scenario construction with CIB, which was facilitated by the CIB scenario experts.[277] *The interdisciplinary researcher team* that was methodologically concerned with the combination of CIB&S, that is the scenario experts and the modelers, comprised six people (with a core-team of three to four). This team covered disciplines as diverse as social sciences, engineering, mathematics, computing and natural sciences.

7.1.1.3 Adding complexity

This type of description is not sufficiently detailed to allow the reader to follow the effects of the methodology. It leaves out all information on trial and error activities, on the techniques that were used beyond CIB and LiWatool, on the role of different actors at different moments, on the data used, and on the conditions under which the different activities of the scenario construction process took place. Therefore, in the following, I add one layer of detail and complexity. The description starts with the immediate context and then zooms into the central phases of the process, including information on loops between activities.

7.1.2 The immediate context: framing and usage

The framing and design as well as the (anticipated and actual) usage of the scenarios are important immediate contexts. In the following, I briefly report on what had been initially planned and what was effectively realized.

7.1.2.1 Framing and design

The *initially planned* scenario methodology is described in the proposal as aiming at "integrated scenarios" through the use of a story and simulation (SAS) approach.[278] The three *aims* of the scenario construction were (cf. e. g. DOC LiWa_proposal: p. 36) as follows.

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276 These actors are in the double role of being at the same time stakeholders and local experts, i.e. expert stakeholders (cf. also in the following Kosow/Leon 2015). The NGOs and the water company can be considered old rivals in the water field, which are brought together, in this project, together with their diverging interests and perspectives. This constellation is prone to conflicts. Furthermore, due to difficult and changing political contexts, the municipality and the city planning unit, which were inexistent when the LiWa project had started, were not included in the scenario group. This was later criticized (cf. scenario group member N t3 44).

277 The Peruvian *scenario group* worked and met monthly in Lima. The modelers worked mainly in Germany (modelers of LiWatool in Magdeburg, climate and catchment modelers in Stuttgart), except for extensive field trips to Lima that were important also for data access and collection. The scenario-expert team was split equally between the Peruvian project coordinator in Lima and his co-worker, and two scenario experts working mainly in Stuttgart.

278 DOC LiWa_proposal: p. 36: "qualitative/explorative scenarios will be used […] as inputs into computer-based models […], thus creating and integrated process between a socio-economic science based ap-

1) To fulfill exploratory-analytical aims within the research project LiWa.
2) To have communicative-discursive effects and to support strategy building processes in the ‘real world’, i.e. in the city of Lima.
3) To support transdisciplinary communication and (knowledge) integration within the LiWa project.

The use of CIB was not explicitly specified at the time of the proposal drafting. The qualitative scenarios were planned to inform two modelling exercises: the climate downscaling and hydrological modeling (work package 3) and the LiWatool simulator (work package 4) (cf. DOC LiWa_proposal: p. 36).[279] Initially, the following role had been ascribed to LiWatool regarding the scenario process (DOC LiWa_proposal: p. 10): *"*This simulator [LiWatool] will form one of the core elements of the project and is developed and applied throughout all work packages. It will receive input information about climate and water balances (WP3) and be used for scenario set-up and evaluation (WP 2, 4)." The proposal goes on (DOC LiWa_proposal: p. 11): *"*Furthermore, the different scenarios and their impacts on the water and wastewater system will be evaluated also by terms of simulations in the concept development stage."

The *effective* framing and finally implemented design was successively adapted to project’s requirements and realities, needs and capacities (cf. e. g. FN March 2012: 432). The CIB method was brought in by the scenario experts and was justified with their particular method interests in CIB and their experience and capacities with this method. At the time of the milestone report in summer 2010, the use of CIB had become an official method of the project.[280] At the same time, it was agreed that the LiWa project should serve me as a case study and that in exchange, I would provide method reflection to the project (cf. FN January 2010 and FN September 2010). Through the scenario experts’ and my interest in the exploration of a combination of CIB &S, a fourth aim had been added to the scenario process, namely to learn from the pioneer application of a full CIB&S process.

The *time horizon* of the scenarios was set to the year 2040 and the *scope* limited to the water system of Lima Metropolitana, Peru, (Lima and Callao), covering “*natural, socio-economic and technical systems"* (FN overall project meting 20120521_23: 75). Both decisions were taken during scenario workshops in Lima.

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proach and a quantitative, natural sciences based approach. More precisely we will use ‘story- and- simulation SAS […].”

279 The planned importance of contributions by the modelers to the integrated scenario development becomes visible through the distribution of manpower and funding of the different modeling teams for their contribution to the scenario work. WP2 accorded 15 months to ZIRIUS, 4 to ifak and 3 to IWS (cf. DOC LiWa_proposal:: 36, for the planned organization (timing, hierarchy and relation) between the work packages (cf. DOC LiWa_proposal: p.32-34).

280 “With LiWa, a new approach is applied in the field of water simulations: Cross-impact balance analysis (CIB) (Weimer-Jehle, 2006, 2008), a qualitative form of systems analysis, is used to generate internally consistent assumptions about social contexts which then are fed into the simulation model of Lima’s water system […] Within LiWa, CIB is used for inter- and transdisciplinary exchange between system modellers on the one hand and social scientists and local stakeholders on the other hand. Furthermore, it is used to support intercultural communication on possible water futures of Lima.” (DOC LiWa_MilestoneReport: p. 15).

During 2010 and 2011, consultations between scenario experts and modeling teams took place to decide, whether and how models should be combined with CIB in order to construct combined scenarios (cf. FN January 2010 and FN September 2010). Finally, a close combination of CIB with LiWatool was realized, with CIB providing LiWatool with qualitative context scenarios to define input data sets for simulations. The climate and hydrological modeling took over the role of supply models, providing the CIB with general information on possible future climate change and providing LiWatool with numerical input on future river run-off from the catchments. The CIB scenario analysis, the LiWatool model building and the climate downscaling and hydrological modelling were all three carried out in parallel. For more detail on the form of combination and on the timing of these three activities, see section 7.3. Thus the data flows that had been initially foreseen between the three work packages were not possible in that form.

Interestingly, in retrospect, the combination of CIB and LiWatool and their integration were perceived by the actors of the scenario core team as an extra (subtext: additional, not funded) activity (cf. e. g. interviews L t3 and M t3). At least officially and in the proposal, the methodological combination of qualitative scenarios and models had been planned right from the beginning. Nevertheless, the activities of modeling and of the CIB were perceived as initially *separate* ones (cf. personal communication with a modeler and with a scenario expert in January 2015). Potentially, this occurred because effectively, both working groups had started their work in a rather independent way. Closer integration was realized mainly during the last three years of the eight-year-long process. In addition, scenario experts and modelers experienced that they did not always have sufficient resources (time, money, capacities) for this integration.

In sum, when the LiWa project started, it was the first attempt to carry out a full combination of CIB with simulation models to construct integrated scenarios. Hence it constituted a pioneer application, a learning-by-doing activity, which required a lot of trial and error by all participants. Furthermore, none of the CIB scenario experts and modelers had much practical experience with any type of combined scenario approaches before this exercise—even if the reference to SAS had been made.

7.1.2.2 Usage

Initially**,** within the project "participative analysis of impacts & evaluation of alternatives" (DOC LiWa_proposal: p. 32) was planned. Furthermore, the LiWa scenario process intended to support the development of a shared understanding of the current and future situation of the water sector in Lima between actors as divergent as the NGOs and the Water Company, practice and research, Germany and Peru. The scenarios were expected to be useful for supporting policy making, especially due to their qualitative-quantitative character (cf. DOC LiWa_proposal: p. 13).

Effectively, the LiWa scenarios (CIB raw scenarios, storylines and the combined brochure) were shared within and beyond the project. Within the project, the scenarios were shared to provide all project partners with a common perspective on the uncertainty of future developments of the water system of Lima. They played the role of supporting a shared understanding of the current and future situation of the water sector in Lima, especially among those actors directly included in the scenario process—and to a lesser degree among other project partners. Furthermore, the scenarios were linked to further project activities such as the development of an action plan and to the simulation of detailed measures with LiWatool. However, this link proved to be less systematic and less narrow than expected and promised at some point of the process. Further use of the final scenarios by project partners was limited, as the project runtime was almost over (end of May 2013), when the integrated scenarios were published (beginning of May 2013). The qualitative storylines (short versions) were assessed by external stakeholders from the water sector of Lima during a semi-public Round Table event (RT III, October 2012) with regard to their desirability, probability and viability in the form of a Group Delphi workshop (cf. DOC_ZB_ZIRIUS_IWS_2012).[281] The integrated scenarios were written for the (anticipated) target user group of external stakeholders in Lima, namely people with professional expertise in the field of water management. They were presented during stakeholder conferences in Lima, Peru (April 2013) and Hamburg, Germany (May 2013). In addition, they are available on the internet and might be further circulated by the members of the scenario group in Lima, who are potential multipliers. Beyond the project, use by external actors is assumed.[282] But whether and how the scenarios entered, stimulated or enriched real world decision-making processes in Lima, lies beyond the scope of this study and also of the LiWa project itself.

7.1.3 Zoom into phase 2 construction of qualitative scenarios with CIB

For the sake of clarity, I analytically divide this phase into sub activities to discern the impacts of different elements of the methodology at different instances.[283] Table 22 gives an overview of the entire methodology including the six activities of this phase, defining their central objectives, timing, methods, actors, data and products.

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281 In the LiWa project, a series of round-table discussions (a type of dialogue forum) were organized to communicate with the potential users of project results in Lima.

282 See e. g. a list of (assumed) impacts in Schütze, M: *Assisting the Desert Megacity Lima in Preparing its Water System for Climate Change*; FONA Conference of BMBF Leipzig, 10./11.09.2013

283 Parts of this phase (namely 2a) were based on my observation period and many events took place in Lima, where I was not present. To analyze this phase from the outside and in part in retrospect, I first relied on process documents: I have traced changes in interim products through a comparison of the D&V lists and matrix structures and contents over time. Second, I relied on reports by project participants and on the validation through key informants. From activity 2b on, the CIB method had direct and method-specific impacts on the process and I was able to follow the activity (at least from afar) in real-time.

7.1.3.1 Selection and definition of descriptors and variants (D&V) (phase 2a)

The central actor of this activity was the Peruvian scenario group, which met in the form of regular scenario workshops facilitated by the scenario experts. After an intense discussion process taking several months, the scenario group first agreed[284] on a list of 13 descriptors and on their corresponding two to three future variants.[285] For an overview of the final D&V, see Table 21.[286]

Table 21: Final list of descriptors and variants (D&V) "Lima's water futures 2040" (Lima Water)

Illustration based on LiWa matrix no. 9. Note that in the matrix the order of descriptors is alphabetical (A-M) in this table it is structured by fields.

Descriptor field	Descriptor	variant 1	variant 2	variant 3
Governance	*A Government*	A1 Government with decision power and vision	A 2 Government without decision power and without vision	
	H Catchment management	H1 Integrated and participatory catchment management	H2 Catchment management without integration	
	B Water company	B1 Public company with autonomy from the government	B2 Public company depending from the government	B3 Private owned company
	C Water tariffs	C1 Low (not cost-covering) tariffs	C2 High (cost-covering) tariffs	
City and society	*D Population*	D1 High population growth	D2 Moderate population growth	D3 Low population growth
	H Urban development	H1 City with urban planning and green areas	H2 City without urban planning and with few green areas	
	E Urban poverty	E1 Increasing poverty	E2 Constant poverty	E3 Decreasing poverty
	F Water consumption	F1 Increasing per capita water consumption	F2 Constant per capita water consumption	F3 Decreasing per capita water consumption
Water infrastructure	*J Water coverage*	J1 Increasing coverage rate	J2 Constant coverage rate	J3 Decreasing coverage rate
	G Water network losses	G1 Increasing water network losses	G2 Decreasing water network losses	
	K Wastewater treatment/reuse	K1 Increasing wastewater treatment and reuse	K2 Constant wastewater treatment and reuse	
	L Water sources	L1 Increasing water sources	L2 Constant water sources	L3 Decreasing water sources
Climate change	*M Water flow in rivers*	M1 Excessive water flow (flooding)	M2 Increasing water flow without risks	M3 Low water flow (severe droughts)

284 Agreement on the descriptors to use and consensus on the variants considered to be possible was not always easy to achieve: There were diverging perspectives e. g. between SEDAPAL vs. NGOs, e. g. with regard to what effects of private water companies are assumed (see e. g. interview expert N t3 4).

285 For the development of the D&V selection and definition over time, see Supplement C_CIB vs. storylines over time Lima Water.

286 The final selection of D&V covering four areas relevant to the water supply of the city of Lima was consolidated by mid-2011.

The selection and definition of D&V was based on the local system knowledge of the stakeholders, who were local experts with specific system perspectives and interests, as well as on the available data on individual descriptors' past, present and future developments. This background information as well as the final definitions of the D&V were documented and justified in so-called descriptor essays (DE) by the scenario experts and individual issue experts.[287] The selection of D&V was an actor-driven activity that was structured by group methods for eliciting the input of experts and stakeholders. The resulting selection of D&V provided the structure of the matrix for the following CIB analysis. The anticipated use of the systematic and semi-formalized CIB (in phases 2b and 2c) influenced this activity: It required the participants to keep the list short and to choose clearly distinct developments, which at best do not contain more than one dimension per descriptor (cf. FN January 2010).

7.1.3.2 Cross-impact assessment (2b)

From 2010 on, during cross-impact workshops structured by the CIB method, the scenario group systematically discussed the interrelations between the alternative descriptor developments. During these meetings, initiated and facilitated by the scenario experts,[288] the scenario group members discussed their mental models of the interrelations of the water management system of LiWa and finally, during several (at least six) and at times intense workshop sessions, agreed on group assessments for 1002 pairs of descriptor developments (cf. DOC and FN 2010 and 2011). This activity resulted in a series of versions of full CIB matrices, i.e. impact networks.[289] The (almost) final version of the CIB matrix (no. 9) was established by the end of 2011, documenting the conceptual group model agreed upon by the local scenario group (see Annex Z). In addition, assumptions on interrelations were stored in an EXCEL sheet in the form of short textual statements, explaining the reasoning for each impact group. These justifications were later imported into the matrix,[290] and also documented in text-form within the descriptor essays.

7.1.3.3 Loop I: going back from the cross-impact assessment to the D&V definitions

The activities 2a and 2b did not occur in a strict linear manner. Instead, considering the development of D&V lists and CIB matrices over time shows that there was *feedback* between the time of the cross-impact assessment and when the D&V were defined. [291]

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287 These are texts of about three to four pages each. For an example, see Annex Y.

288 The interrelations between future developments were assessed on a seven-point scale from -3 to +3. Note that the standardization convention was applied in the Lima Water case.

289 For the following section, see Supplement C_CIB vs. storylines over time Lima Water.

290 For this purpose, a new feature of the CIB software had been developed by the scenario experts.

291 In parallel, both activities 2a and 2b were initially prepared and influenced by the scenario experts and then were worked over, changed and appropriated by the scenario group, which became the most influential actor with regard to the final results.

Table 22: Overview of the methodology of the CIB scenario construction (phase 2), elements with central impacts bold and underlined (Lima Water)

Activity	**2a Selection and definition of descriptors and variants**	**2b Cross-impact assessment**	**Loop I**	**2c Balance analysis and selection of raw scenario sample (Annex BB).**	**Simplification of sample I (March 2012) (Annex DD)**	**Simplification of sample II (March 2012) (Annex EE)**
Objective	*What are the central system elements (descriptors) and their possible future variations (variants)?*	*Do descriptor variants impact each other? If yes, are these hindering or promoting impacts and how strong are they?*	*What feedback occurred between activity 2a and 2b?*	*What are (central) internally consistent configurations (= scenarios) of the LiWa9.cim matrix?*	*What are the reference scenarios/ What are the central CIB configurations representing the four scenario families?*	*What is an unambiguous sample of central CIB configurations representing the four scenario families?*
Timing	2009-2011	2010-2011	2010	autumn 2011	March 2012	March 2013
Actors	**<u>Scenario group</u>** CIB scenario experts	**<u>Scenario group</u>** CIB scenario experts	Initially, CIB scenario experts steering during 2a and b, later **<u>scenario group</u>** taking over both steps (after milestone evaluation of LiWa summer 2010).	**<u>CIB scenario experts</u>** Scenario group	CIB scenario experts anticipating communication of scenarios to external experts.	Modelers preparing simulation of scenarios asking scenario experts.
Methods	scenario workshops; expert and stakeholder elicitation (CIB anticipated)	scenario workshops (cross-impact workshops); expert and stakeholder elicitation. **CIB** (specific form of impact assessment) .	CIB cross-impact assessment, 'muddling through'	**<u>CIB balance algorithm, ScenarioWizard (CIB software)</u>** Desk research Software training	**<u>Selection by scenario experts</u>**	**<u>Selection by scenario experts</u>**
Data	Stakeholders' local systems knowledge; given information on past, present and future developments	Expert judgments (group assessment) based on discussion of different mental models on interrelations.	Scenario experts system perception vs. scenario group's system perception.	CIB matrix LiWa9.cim	LiWa scenario sample n= 16 CIB configurations; grouped content wise into four scenario families.	LiWa reference scenarios n= 8
Product(s)	*List of descriptors and variants (D&V) (no 1 to no 9);* *Descriptor essays*	*Full CIB networks (CIB matrices* *No 4- No 9).* *Including textual justifications of impact assessments (also added to the descriptor essays).*	*a) Adaptation of D& V list at the beginning of phase 2b.* *b) Changes of D&V structures and matrices between versions 4 and 6.*	*LiWa scenario sample n= 16 CIB configurations, also presented in scenario tables.* *Sample grouped content wise into four scenario families.*	*LiWa reference scenarios n= 8.*	*LiWa reference scenarios n= 7.*

The comparison of the D&V lists and matrix structures shows that the list of D&V (first full list in 2009) was still subject to change until mid-2011. Most important changes occurred at the very start of the cross-impact assessment. The preliminary list of D&V (from September 2009) was considerably adapted and refined into the list building the structure of the first full CIB matrix in 2010 (no. 1 in May 2010): Five descriptors were completely newly defined and four others were considerably changed with regard to their variants. Scenario expert L reports that it was the *cross-impact assessment itself* that triggered the most important changes to the definition of the D&V.[292] These changes occurred during the beginning of the cross-impact assessment. These adaptations of the D&V structure during the cross-impact assessment in turn required checking whether the impact assessments needed to be adapted in response (feedback to 2b). After this initial and quite dramatic shuffling of the D&V lists, all later changes were rather marginal until the final version (no. 9 at the end of 2011).[293]

7.1.3.4 Balance analysis and selection of the raw CIB scenario sample (2c)

This phase can be further divided into two main sub-activities: first the composition of the raw CIB scenarios and the selection of the scenario sample that was supported by the CIB analysis; and second, the sampling activities going *beyond* the raw CIB output. Both activities were carried out mainly by the scenario experts.

A CIB analysis of the matrix with the help of the ScenarioWizard software program was carried out to identify internally consistent configurations (i.e. scenarios) out of a theoretical number of around 140,000 possible ones. The maximal consistency level allowed was fixed at -1, which resulted in four fully consistent configurations and three slightly inconsistent ones. As this selection did not cover the

292 Scenario expert L t2 145 ff.: *"[…] but what has changed or influenced the descriptor essays more is the discussion in the CIB matrix. Initially, we had tried or said that we first needed the descriptor essays and definition and that we would take them as they were described. During the process the influences are assessed. But it turned out that it was the other way round, so when discussing the influences, it was said that we should actually take the descriptor differently, because as it has now been described at the beginning, it is not reasonable to use it like that.*
HK: *This means it was actually the greater influence [compared with the quantification] on the descriptors?*
Interview CIB scenario-expert L t2: "*Yes, I would say that."* (cf. also Interview G t1 46).

293 With one exception, the transition from matrix 4 (mid 2010) to matrix 6: The first entirely filled matrix (no 4) was filled mainly by the scenario experts in summer 2010, due to the pressure to produce and report on results for the milestone report. This version was based on the scenario groups' ideas documented in a prior influence analysis that had been carried out on the level of descriptors. Afterwards, an empty(!) matrix was newly filled by the scenario (from version no. 6 on). This reappropriation through the scenario-group became apparent through the important changes from matrix no 4 to matrix no 6: First, the descriptor J 'water deficit' is replaced by 'connection rate to the public water net'. An ensemble analysis of both matrices (Annex AA) shows that the impact judgments stored in matrix 4 and 6 diverge considerably. Furthermore, this transition was marked by other changes: Descriptor *N "international influences"* was omitted, the variants of descriptor C "*tariffs"* changed from C1 "low" to "supported by subsidies" and C2 "high" to "cost effective, the variants with regard to descriptor I "*urban development and green area"* become more differentiated. Descriptor M *"Climatic change"* is extended and gets further dimensions, namely *"precipitation and risk."*

full range of future climate alternatives, scenarios for *dry* climatic conditions were included in the sample by pre-selecting the alternative "M3: decreasing precipitation and droughts" for the analysis of the matrix. Finally, the overall sample consisted in 16 CIB configurations.[294] The influence of the CIB method on this activity is strong, but the selection of the 16 configurations is not automatic. It also results from interpretation and manipulation by the scenario experts, namely in *sampling activities beyond CIB output*: The resulting 16 configurations were interpreted and structured into *four scenario families A- D* with the scenario family B comprising two variants. The families were identified and given a title by the scenario experts (by end of 2011):[295]

- "Scenario A: Climate stress meets governance disaster
- Scenario B: The tragedy of isolated measures
- Scenario C: The opportunities of mesoscale actors
- Scenario D: Climate resilience by governance"

The scenario sample was summarized in the form of a *scenario table*. The sampling results were presented to and discussed with the scenario group, Peru, in autumn 2011. In parallel, three *software workshops* on ScenarioWizard were carried out with the Peruvian stakeholders in Lima (by the scenario experts, including myself) to enable them to use the CIB software and to fully understand the sampling.

7.1.3.5 Two simplifications of the sample (2d)

During the further process, the scenario sample was simplified at two moments. First, *reference configurations* for each family were selected by the scenario experts to reduce the size and complexity of the scenario sample to eight CIB configurations, see Annex DD (cf. FN March 2012: 209-216).This was done for easier communication of the scenarios to *external stakeholders* (see section 7.1.4 below). Second, the sample underlying the LiWatool simulations in March 2013 was, for practical reasons, reduced to seven CIB configurations (Annex EE), by taking out the climate variation of scenario B. This was done at the request of the *modelers,* who asked for unambiguous configurations per scenario family for scenario simulations, see section 7.1.5 below.

294 A scenario expert explains, why this was done (FN January 2012: 51 ff.):
"How are the storylines extracted from LiWa9.cim? […] As the descriptor 'climate change' is mixing two dimensions: climate variability AND its effects on the city of Lima, some variants are excluded by the Matrix in some scenarios. But the first part of the climate change descriptor is completely independent of the City of Lima. Thus, we add manually the missing climate alternatives. i. e. we accept a 'methodological error' to obtain both possible future variants of climate change. Aim: completeness of scenarios."

295 For more information on the scenarios, see Annex S and the official project website: ULR: http://www.lima-water.de/en/pp2.html.

In sum, during sampling beyond CIB output, the scenario experts' influence was strong. Later, in April 2013, the LiWa scenario sample was subject to a last minute change, which entailed considerable modification of scenario family C (see Annex FF, see also section 7.1.7).[296]

7.1.3.6 Products: CIB matrix and raw CIB scenarios

Central *products* of the qualitative scenario construction with CIB (phase 2) were the *CIB matrix* (including justifications of impact assessments) (no.1-no. 9); the scenario *samples of raw CIB scenarios* (reference scenarios) represented by *scenario tables* and *descriptor essays* defining descriptors, justifying selection of variants and verbalizing the impact assumptions.

7.1.4 Zoom into phase 3* storyline writing

The raw CIB scenarios were further elaborated into *storylines*, describing each of the four scenario families in the form of more-or-less narrative texts to communicate the scenarios to external stakeholders and experts. Table 23 gives an overview of the methodology including the three central activities of this phase:[297]

Table 23: Overview of the methodology of the storyline writing process (phase 3*), elements with central impacts bold and underlined (Lima Water)

Activity	**Story writing ‚long versions'**	**Storyline writing 'short versions'**	**Storyline writing Loop II to he matrix**
Objective	*How to describe raw CIB scenarios (internally consistent configurations) in form of text?*	*How to present the LiWa scenarios in a very short way to externals?*	*Whether and how to integrate the comments from external stakeholders into LiWa scenarios?*
Timing	Winter 2011/2012	Spring 2012	March-June 2012
Actors	**CIB scenario experts (including HK) writing** (modelers commenting student assistants translating)	**New scenario group member P writing** Scenario experts doing consistency check	External stakeholders **CIB scenario experts**
Methods	CIB indirectly through data (storyline writing)	CIB indirectly through data (storyline writing)	Expert Workshop/Round Table CIB
Data	New CIB software products: CIB scenario table Wizard protocol including impact diagrams Descriptor essays	Long versions of storylines (reference scenarios indicated) Scenario table	Short versions Comments by external stakeholders Impact diagrammes CIBmatrix No 9
Product(s)	*Long version of storylines in German, English and Spanish.*	*Short version of storylines in Spanish.*	*Refined short versions of the storylines,* *CIB matrix No 10*

[296] For an overview of central CIB matrices and samples of the Lima Water case over time, see Annex R.

[297] Access**:** To analyze this phase, I mainly rely on the following sources of evidence: FN 2012), including my second field trip to Lima; Interviews t2; Storyline products (DOC). Issues linked to the redaction of the integrated scenario brochure are presented in phase 5, Integration.

7.1.4.1 Storyline writing 1 'long versions' (3*a)

First, a long version of the storylines was developed (cf. FN November_December 2011 and FN January 2012). Their text was narrowly based on the raw CIB scenarios:[298] During the LiWa project, three new features of the CIB software were developed by the scenario experts to support the storyline writing process. Through automatic plotting of information stored within the matrix, these were intended to provide a basis for developing textual descriptions of the scenarios (cf. also 3.3.2):[299] They are as follows.

- The *scenario table*, arranging the CIB scenarios in table-form (Annex BB).
- The *protocol*, extracting the textual descriptions and justifications for every scenario (Annex GG).
- *Influence diagrams* for individual descriptor states (Annex GG).

These features were indeed heavily used by the scenario experts to prepare a first draft of the text in German. This text was based on the structure of the CIB scenarios provided by the scenario table and the content of the individual scenario protocols, including input diagrams. In the role of a CIB scenario expert, I was involved in this activity by preparing a first text draft in German. I was supported in this effort by my scenario expert colleagues, mainly in Germany (cf. DOC Storylines LiWa9 290112_first comments). In addition, the working versions of the descriptor essays were essential input data, providing D&V definitions going beyond the not very precise or detailed short titles used in the matrix. These long versions of storylines describe each of the four scenario family on about four pages of text. Still, the storylines translate the original CIB table: All 16 CIB configurations of the CIB scenario sample are covered through variants within the text, either in the form of parallel alternative developments (e. g. for scenarios B1 and B2), or, for slighter variations, in the form of formulations like: "experts considered that it would have been possible, too, that…". Overall, the writing of the long versions was an actor-driven activity that was indirectly, yet strongly influenced and steered by the CIB method in the form of input data. [300]

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[298] The CIB method influenced this activity only indirectly, as CIB is not a storyline writing technique. Furthermore, no other explicit storyline-writing technique was used.

[299] To be precise, initially the plan was to produce 'hypertext' scenarios with different layers of information, and the new features had been developed at this aim.

[300] In the following, the corrected long versions of the storylines have been translated into the other project languages by (project external) *student assistants* and (internal) *scenario-group members*. Every translation was checked with regard to its consistency by the *scenario experts*. Furthermore, external *student assistants* prepared illustrations for the LiWa storylines, based on the tableau and on short definitions of the descriptors and their variants (cf. FN January 2012). In order to ensure the adequacy of these illustrations and their consistency with the CIB scenarios, I met them several times in Stuttgart (cf. FN January 2012). With regard to translations, the impact of actors was high, but with antagonistic effects: threatening consistency (student assistants) and controlling consistency (scenario experts).

7.1.4.2 Storyline writing 2 'short versions' (3*b)

In the spring of 2012, the long versions of the storylines (in Spanish) were condensed into short versions of one page per scenario family. The aim was to produce a short text that could be used to familiarize external experts and stakeholders with the LiWa scenarios (e. g. during the so-called Round Table events).[301] The short versions are textual summaries of the long versions (FN field trip Lima II March 2012: 386 ff.).[302] These summaries were written mainly by a new member of the scenario group, expert P, who had just recently joined one of the partner organizations, a NGO working on urban development. They were commented on by the scenario group and quickly checked by the scenario experts with regard to their consistency with the CIB raw scenario table before the second Round Table (RT II) (cf. FN field trip Lima II March 2012). These short versions translate the CIB sample of eight CIB *reference* scenarios and were communicated together with the simplified scenario table comprising scenarios A, B1, B2, C and D, plus climate variances in A and D and B2 (see simplification I).

7.1.4.3 Loop (II): dealing with comments from external experts

On the occasion of the second Round Table (RTII), these short versions of the storylines were presented to and discussed by a round of 30 external stakeholders from the water sector in Lima. The aim was to socialize and validate the LiWa scenarios (cf. FN field trip Lima II March 2012: 178 ff.). Prior to the RT II event, among the LiWa project team, no definite decision had been taken, as to how much impact the external stakeholders' comments should have on the LiWa scenarios, and especially on whether the CI-matrix would be reconsidered. Thus, a change of the scenario sample would still have been possible at that point (cf. FN field trip Lima II March 2012). During the Round Table event, stakeholders were briefly introduced to the scenario work of the LiWa project in a talk given by a scenario expert. Later, they were split up into working groups, each one facilitated by a scenario group member or a scenario expert, to work over one of the four scenarios.[303] After the RTII, the comments and critiques of these stakeholders[304] were included in the storyline texts in the form of

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[301] In the LiWa project, a series of round table discussions (a type of dialogue forum) were organized in Lima to communicate with the potential users of project results in Lima.

[302] "The *storylines have been translated into Spanish and processed by the scenario group in recent weeks […]. Scenario group member P, K's successor has, although (HK: or possibly because?) she was not involved in the scenario construction process, written 1-page summaries of scenarios, A, B (B1 + B2), C and D. These formed the basis for the working groups at RT II (together with the CIB-scenario tableau).*"

[303] Working groups had been equipped with multiple materials distributed in the working room, i.e. CIB: scenario table, CIB Matrix, protocol per reference scenario, including impact diagrams, working versions of descriptor essays; storylines: long and short versions; simulation: first outputs summarized on one poster per scenario.

[304] The scenario experts have grouped the comments of the external experts and stakeholders into three types, 1) *additions*, i.e. aspects that had been missing in the scenarios, 2) *explanations* e. g. on definitions or on influence logic that had not become clear in the short versions of the storylines and 3) *non-intuitive phenomena* such as the parallel existence of a private water company and (still) rising losses in the water

more precise descriptions and explanations of those scenario aspects that had been perceived as counterintuitive. They also led to adaptations of some of the *justifications* of the impact assessments stored in the CIB matrix. This version (no. 10) was changed on the level of explanations and justifications of impact assessments only. Impact judgments—the inner structure of the matrix and the scenario sample—were not changed.[305]

Overall, the storyline writing process was an *actor-driven activity*. Still, CIB indirectly impacted this process through the CIB-generated data and more directly when scenario experts were dealing with the comments from the external stakeholders.

7.1.4.4 Products: storylines

The two central versions of the storylines were as follows.

- The **long version** of the storylines prepared by the scenario experts (DOC LiWa Storylines _long first comments 20120112)).
- The **short version** of the storylines prepared by the scenario group member P and the scenario experts (DOC LiWa Storylines_short 20120314).

For a detailed characterization of these two versions, see Annex T. [306]

network (in scenarios B and C) (cf. FN iteration matrix vs. storylines 20120423). It was decided by the scenario experts that comments of type 1) and 2) should be dealt with on the textual level, by adding and refining the textual descriptions within the storylines. As to comments of the 3rd type, the CIB *matrix* (*no. 9)* was consulted to check whether the logic embedded in the impact network would hold against this critique or if the impact assessments should rather be adapted in response. This was supported by the new software feature, the protocol an impact diagrams.

305 Furthermore, during the revision of the matrix no. 9, an *error within the matrix* was uncovered, an internal inconsistency between judgment in numbers and its verbal justification (FN iteration matrix vs. storylines 20120423: 39).Further field notes report (FN Internal ZIRN meeting 20120515: 51)*: "There is an inconsistency in the matrix LiWa9 with regard to the impact from K on L: the justifications/reasoning … is not in line with the numbers of the judgment group*"). How is this problem dealt with? Scenario experts compare information and discuss possibilities (cf. FN Internal ZIRN meeting 20120515*:* 52 ff.). Finally, they decided*: "We decided to follow the original group statement. HK will adapt the justification in the matrix in line with the original group statements reconstructed by expert M. In consequence the matrix is NOT changed due to this reason. Overall, the matrix itself is not changed at all in consequence to the RT discussions."* (cf. FN Internal ZIRN meeting 20120515: 69).

306 Deviant from the initial design (cf. phase 1 "framing"), no final stand-alone narrative scenario product was published in the Lima Water case. Instead, the final short versions of the storylines build the basis for the narrative part of the integrated scenarios.

Table 24: Overview of the methodology of the matching process (phase 3), elements with central impacts bold and underlined (Lima Water)

Activitiy	SPECIFICATION		QUANTIFICATION			BUNDLING
	Translatable parts	**Indicators**	**Base year**	**Status quo**	**Time series**	
Objective	*What descriptors to translate?*	*What indicators represent the descriptors(partial/ full translation, split etc.?)*	*What base year?*	*What is the status quo?*	*What time series do represent the variants?*	*How to bundle?*
Timing	*First half of 2010*	*From 2010 on, last split in 2013 (descriptor H, green area)*	*First decision in2009* *Second decision in 2013*	*From 2010 to 2013*	*2011-2013*	*2012 and 2013 (for simulation runs)*
Actors	**<u>Modelers</u>** <u>(deciding)</u> Scenario experts (initiating and driving)	**<u>Modelers</u>** representing LiWatool possibilities Scenario experts representing scenario groups ideas Issue experts SEDAPAL in the background	**<u>Modelers</u>** (final decision) SEDAPAL in the background	**<u>Modelers</u>** (final decision); Issue experts and scenario experts (contributing) Stakeholders influencing ;) SEDAPAL in the background	**<u>Modelers</u>** (final decision, but driven by scenario expert discussions)); Issue experts (contributing) Stakeholders influencing ;) Scenario experts (pushing and facilitating process, proposing TS checking consistency)	Modelers (implementing) Scenario experts (consistency check) Scenario group (changing scenario C)
Methods	(LiWatool and CIB indirectly) consultation modelers/scenario experts	(LiWatool indirectly, CIB very indirectly over descriptor essays) verbal-argumentative translation Current practice Expert Workshops consultation modelers/scenario experts Rapid Prototyping	…in consultation with scenario experts	desk research; expert interviews; negotiation	Literature review, expert elicitation; verbal-argumentative translation; Expert Workshops consultation modelers/scenario experts LiWatool *indirectly*: adaptation with regard to simulation results: LOOP IV	(CIB indirectly) consultation modelers/scenario experts **<u>Software</u>** for automatic read out of input parameters
Data	LiWatool requirements; Raw CIB scenarios/ scenario table	List of 10 out of 13 descriptors; Descriptor essays; LiWatool requirements Num. Information on past, present future developments (Data availability)	Num. information on past and present developments (Data availability, data quantifiability – some descriptors are hard to describe numerically e. g. “governance”	Num. information on past and present developments (Data availability)	List of indicators; Num. information on past, present future developments (Data availability) CIB raw scenarios Descriptor essays	List of indicators and time series; **<u>CIB scenario table</u>**
Further conditions	Activities competing for limited project resources Duration Timing					
Product(s)	*List of 10 out of 13 descriptors; 9 being input data, 1 being split into an input factor and an output (consumo)*	*List of indicators*	*One base year for all indicators*	*Status quo for all indicators*	*List of time series until 2040*	*Input data sets (internal EXCEL sheets as basis for simulations (TS 1- TS4)* *Input–tables in integrated scenario brochure*

7.1.5 Zoom into phase 3 matching (level I): definition of numerical input data sets

The raw CIB scenarios resulting from phase 2 have been further processed into numerical input data sets. They were aimed at driving the LiWatool[307] simulations of the scenarios, and thus constitute the first half of the numerical scenarios. [308] I have split the matching phase into three overarching activities—3a) specification, 3b) quantification, and 3c) bundling—each one comprising further sub-activities. In addition, two feedback loops with other activities occurred, one from the definition of indicators to the CIB analysis (loop III), and another one from the simulation back to the definition of time series (loop IV). Table 24 gives an overview of the methodology of the different activities of the matching phase.

The process of matching, prepared in 2010 during meetings between scenario experts and the modelers, was actively started in 2011, went on through 2012 and was finally completed in spring 2013, together with the integration and iteration activities (cf. FN and DOC of these years). In total, actors were working on the matching during a three year period—in parallel to several other activities. The matching was the predominant activity of the combined CIB &S process during my observation period. Due to the sheer amount of empirical evidence with regard to the matching phase, the following presentation of it needs to be rather general. For more detail, see Annex U, in which, the examples of the descriptors tariffs and poverty are used to illustrate, how complex the matching task was, even for what could be assumed to be easy cases (e. g. tariffs); where the difficulties in tricky cases (e. g. poverty) lay; and finally, how individual matching solutions were found for every descriptor.

Overall, the matching process was characterized by actor-driven activities. It was marked through decisions by small groups, consisting of modelers and scenario experts, including issue experts and stakeholders for individual issues. The scenario group as a whole was not included. The water company played an important role, albeit in the background. It was the main data provider and its data was the most crucial empirical basis for the LiWatool modeling.

7.1.5.1 Specification, i.e. definition of indicators

Overall, the definition of indicators was an actor-driven activity: The LiWatool modelers were the central actors, who had the final word on what descriptors were translatable and by what indicators. The modelers acted in the role of the model's advocates, always considering the question: What information is the LiWatool simulator able to process (in the form of model input) and what is it not

[307] For more information on LiWatool, see phase 4 (section 7.1.5).

[308] To analyze the matching phase, I mainly rely on the following sources of evidence: FN (2011, 2012 and 2013); Interviews t2 and t3, and DOC (mainly input data sets, selected descriptor essays for illustration).

able to process? They decided to translate ten of the descriptors into model input.[309] But the modelers were not acting alone; the general matching process was initiated and driven by the scenario experts (including myself), who were acting in the role of the scenario group's and CIB raw scenarios' advocates: They were considering the qualitative CIB definitions and checked, whether the chosen indicators matched the scenario group's ideas behind and understanding of the qualitative formulation of descriptors They also brought the scenario group's proposals for indicators into the discussion.[310] Thus, the specification phase was marked by issues of social integration, bringing together different actors in the project (with their interests, priorities, modes of communication etc.); and cognitive integration, bringing together the way the modelers, the scenario experts and, indirectly, the scenario group, understood the system.

With regard to the methods, LiWatool and CIB indirectly influenced the definition of indicators. The LiWatool simulator (for more detail see 7.1.6) did so indirectly through its requirements and interface options. At the same time, the LiWatool simulator as well as its so called 'Lima in one block model' (cf. below) were still under construction during an important part of the matching process, which made them open and flexible to a certain degree. The method CIB had an indirect impact as the CIB raw scenarios were used (table and matrix, defining the descriptors with short titles only) as well as the descriptor essays that contained more extensive definitions of the D&V.

For some descriptors the numerical indicators were already implemented or strongly hinted within the CIB matrix (e. g. water network losses, population growth) and the selection of indicators was rather easy and consensual (see. e. g. the indicator for tariffs, PEN/m3, Annex U). To translate descriptors into indicators that were less evident to find, desk research and expert workshops were carried out by scenario experts, modelers and issue experts to find adequate quantitative representatives. Overall, indicators were defined through a kind of verbal argumentative reasoning, which was oriented through the following conditions.

a) The *current practice of indicator use***:** We use this indicator, because it is the typical one, i.e. the one that is used by local actors as the water company in Lima, e. g.
b) *LiWatool requirements*: We choose this indicator, because LiWatool needs this information and can process it.
c) *Data availability*: We choose this indicator because we have data for it i.e. available numerical information on past, present and especially future developments. Data availability played a role, as actors were anticipating the next step of matching, i.e. the definition of time series.

309 The numerical correspondence to the descriptor 'consumo' was later split into an input aspect and a calculated output (Cf. FN February 2013: 164-166), see section 7.1.6, too.

310 The scenario-group as a whole was not directly active in the matching process, some members contributed in the role of issue experts (e. g. with regard to the indicator for poverty); further issue experts beyond the scenario group member contributed to this activity, too.

For the most evident example, please see the description of the decision to use the indicator socio-economic levels (NSE) representing the descriptor poverty (Annex U). This was a contested indicator not fully matching the scenario group's ideas behind the qualitative descriptor.

Agreement on the indicators (cognitive integration) was achieved through repeated consultation between scenario experts and modelers as well as expert workshops (cf. FN meeting ifak_ZIRN Stuttgart 20100118, FN Ifak-HK meeting Magdeburg 20100908, and all FN from 2011). These were organized mainly in 2012, including the issue-experts among the project partners in the discussion, e. g. with regard to tariffs (cf. FN January 2012, and FN WS tariffs II 20120606), but also with regard to climate change and green areas.

7.1.5.2 Loop III: definition of numerical indicators with impacts on definitions of qualitative D&V

The discussion of the (albeit easily translated!) indicator for the descriptor *tariffs* among modelers, scenario experts and issue experts led to (slight) adaptations of the qualitative definitions of the descriptor and its variants (D&V). On the level of the *structure* of the matrix, this adaptation became visible through the new labels of the *qualitative* variants from "low/high" (2010) to "subsidized/cost effective" (2011), and to "not cost effective/cost effective" (2012).[311] Initially, with regard to its content, the descriptor tariffs had included prices for water provided by the water network *and* by water tanks. This second part was, after the numerical precision of the indicator, excluded from the definition of the qualitative descriptor.[312] These adaptations in turn required checking within the CI-matrix whether the impact assessments still made sense with the slightly adapted definitions, that is the consistency of the older impact assessments with this new understanding of the descriptor had to be checked through a comparison with the matrix. As a consequence of this check, no changes occurred to the CIB matrix.

7.1.5.3 Quantification, i.e. definition of time series (TS) (3b)

Overall, the definition of time series (TS) was an actor driven activity, too. Modelers had a central role and the final say with regard to the definition of the base year, the (in some cases only assumed) base year values (i.e. the status quo) and the time series until 2040—as finally, they had to feed their model. Still, they did not decide alone, but were in constant consultation with the issue-experts and the scenario experts**,** also during workshops. These supported the process with their information on past, present and future developments of indicators. The scenario experts provided considerable

[311] In the Spanish original "subventionada/sincerada" (2011) and "no sincerada/sincerada" (2012). For the development of the descriptor and variant selection an definition over time, see Supplement C_CIB vs. storylines over time Lima Water.

[312] "The prices for drinking water supplied by water tanks are not analyzed." (DOC Descriptor essays final, descriptor essay on tariffs).

data input, for instance through repeated desk research by scenario expert M on already available data resulting in suggestions on numerical time series, In addition, they pushed and facilitated the process, e. g. by organizing workshops (e. g. FN throughout 2011 and 2012) and by checking the consistency of the chosen time series with the CIB definitions (cf. FN December 2012 and FN January 2013).

Considerable issue expertise was brought in by German research partners from the LiWa project, who did, for some descriptors, intense research on past, present and possible future developments (especially with regard to tariffs, green area, climate change) and by Peruvian project partners mainly from the water company. They contributed especially with regard to indicators concerning the water network as for example coverage rate and network losses. Some of them were members of the scenario group, others not. In general, the water company SEDAPAL made important (if not the central) contributions to the empirical database of the LiWatool model. They had a monopoly position with regard to much information and were identified by the modelers as the potential later users of their model. In consequence, they had a particularly important position in the process. This was seen as critical by some of the NGO stakeholders (cf. e. g. interview expert N t3 58, 65).

Base year

The water company SEDAPAL also had a strong impact on the decision on the *base year*, due to the question of what the newest (and in their view 'best', meaning most optimistic) information on the status quo of the water network was. In 2013, the base year was adapted from initially chosen 2009 to 2011, and thus heavily based on official information from SEDAPALS latest year book from 2011 (cf. e. g. FN February 2013: 99). This change of the base year also happened due to the *length* of the process of matching, as in 2013, for all indicators newer empirical data had come up. The change was linked to issues of data availability and to issues of political sensitivity of status quo data.[313]

[313] Interview scenario-expert L t3 41, my emphasis: "*Changes in the time series were related to the question, which is initially the base year. The problem arises that some, in particular SEDAPAL, don't wish to deal with the old inferior numbers, they are already history* **…** *The longer the process lasts, the more new figures come. The modelers were, for example, very open to new figures. The problem was that you kept on having to wait for new figures. Perhaps we simply should have been more stringent "Base year is 2011, we'll stay there ...." But the modelers were rather open, especially when something new came from SEDAPAL. It was then also a point of discussion between us."*
Interview modeler O t3 43: "*What's more, we had been saying until now that until 2013, we would either accept constant values or a unified development for all descriptors. However, we have now received very current values for 2013, i.e. ANF with 30% instead of 34%. How do we deal with it? I have now put that at 30% for 2013 and postponed the series accordingly, so that the increase from 30% to 40% or the decrease from 30% to 25% takes place. But at the same time I have to—would like to—simulate the old values for 34% for 2011, as I still do the comparison of the results from 2011 with SEDAPAL's Annuario 2011 to obtain a certain reference and to have a certain basic confidence in the model. I have agreed with expert L that we will use the values from 2011 as a basis. Based on this, addressing the final values of the time series for the year 2040, and not letting ourselves be irritated by the slight improvement of 2013, but staying with 2011 as the base year, as the year for which we have complete information. But that would be something where you would have to specify next time how you deal with something like that."*

Status quo

Establishing the *status quo data* for the chosen indicators in the selected base year was a joint task by modelers (who took the final decision), issue-experts, scenario experts, and stakeholders. It was based on desk research, expert interviews and, at times, also negotiation. This was especially the case when the numerical information on past and present developments that was available, through own research by the LiWa project, did not match the, so to say, combat numbers, that were used by the stakeholders in Lima, see box below. During interviews, scenario experts and scenario group members agreed that for some indicators, the definition of the status quo was the most delicate and decidedly non-trivial task of matching—because then qualitative formulations of the *current* state of the system had to be clearly specified by numbers.

Performance indicators and numbers of combat

The Peruvian actors that *were* included in the matching process played a double role of issue experts and stakeholders at the same time (cf. Kosow/ Leon 2015). During the definition of the *status quo*, especially the water company was interested to see the most *optimistic* numbers with regard to the water system (so to say, their *performance indicators*) and the most *dramatic* with regard to the daily water consumption per capita to justify their saving policy (their political combat number). This political sensibility of the status quo values, (the numbers of combat) was evident with regard to the issues of green area (indicator for urban development), too: On the question of how much m^2/capita of green area people do currently have in Lima, German research partners provided numbers based on their own research that were *less dramatic* than those generally circulating in Lima. The latter were preferred by the NGOs because they were perceived as more politically useful to emphasize the importance of the issue (cf. e. g. interview scenario expert L t3 38, 39): *"Another thing which also relates to quantification is the green areas. We have measured a different figure to the official figures. And initially I do not find it problematic either, in principle." "Here, for example, it becomes clear that even political factors are involved. Lima uses the 2.4 m^2*/capita *to demand that more green spaces are created. And they are scientifically measured by the LiWa project to have a status quo of 4.0 m^2*/capita. *Possibly politically undesirable as it looks as if Lima is not so bad. […] We have perhaps underestimated in the quantification how politically sensitive these figures could be."*

Time series

The process of translating the qualitatively expressed ideas of the scenarios into numbers, i.e. *time-series* being usable in the form of input data by LiWatool, was based on information on past, present and future developments on the system as documented in the descriptor essays and as provided by project partners. For every *indicator,* existing *numerical* information on past, present and potential future developments (in the form of time series, projections, predictions, scenarios etc.) was searched. From the range of existing numerical information, representatives more or less matching the qualitatively defined descriptor developments were selected. This approach was possible only for those descriptors, where numerical information, on future as well as current developments, was already *available* (e. g. demographic development). For some descriptors, this information did not preexist, but was newly created by the LiWa project. This was then created through research by project partners with issue expertise on specific descriptors (e. g. climate change, tariffs, green area). Especially with regard to information on *future* developments, the definition of time series often relied on expert estimations of the scenario experts, modelers and project partners (for example in the case of poverty). In sum, quantification was realized through some kind of verbal argumentative reasoning and decisions were based on expert judgments.[314]

As during the matching process (potential) threats to inconsistencies were observed (e. g. the error in time series and others, cf. Loop IV below and FN Nov_Dec 2012, and FN January 2013), I carried out a systematic *consistency check*. I compared the proposed time series with the qualitative definition of descriptors and variants and checked the documentation of both in the descriptor essays (cf. FN Nov_Dec 2012 for details). I communicated the results of this comparison to the modelers and the scenario experts (cf. FN January 2013). This led to adaptations of the time series and, to a minor degree, also of the descriptor essays (cf. FN January 2013 and FN February 2013).

7.1.5.4 Adaptation of time series after simulation (Loop IV)

The initial time series for *poverty* were considerably changed and adapted over time. This occurred mainly due to a *loop* between LiWatool simulations and the matching process. During this loop, input data and ad hoc simulation assumptions were changed in function of simulation results (Loop IV) (cf. phases 4 and 5). The background was that during the fourth Round Table event in autumn 2012 (RT IV), there was a live simulation with LiWatool using an input data sheet, in which time series for sinking and increasing poverty were confused. The simulations, using these wrong time series, were nevertheless providing supposed intuitively right results with regard to water balances. Still, the error was uncovered and reported by scenario expert L (cf. FN Nov_Dec 2012).[315] In response, the error was corrected by the modeler. Yet, with the corrected input time series (January 2013), the overall simulation results, namely the water-balances per scenario were not as dramatic as expected: "Problem: We don't have a problem anymore" (cf. FN February 2013: 202). This means the resulting water balances no longer matched the (intuitive) qualitative scenario ideas (cf. FN January to March 2013). In response to the simulation results that did not fit the expectations, the indicator NSE was split into *four* time series. All of these four time-series(A, B, C and D & E), were now each varied across scenarios. They included more differentiated assumptions on the development of the middle class and the rich—and 'brought the problem back':

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314 The modelers did not see a need for a more formalized approach. The general attitude was that one cannot entirely formalize this step anyway, as it always requires supplementary assumptions (cf. FN Ifak-HK meeting Magdeburg 20100908).)

315 CIB scenario-expert L reports he has discovered an error within the input data: *"LiWatool training was on Monday. That was where we got the model and the values which were used for the scenario simulation. It occurred to me that he [had] swapped the values for poverty in scenario A-B-C with those of D (I hope not for the RT4 simulation). There was also general criticism for the poverty values (NSE D+E), which are too high. We [had] already had the tiresome discussion... But depending on the values, you obviously get other simulations results. It would therefore be important to recheck the data (or have the data checked). It is important to have the data source; Expert O was not able to say anything about that. Expert M was ill for the whole of last week and unfortunately missed out on everything."* (FN Nov_Dec 2012: 66).

> Interview modeler O t3 40, 41: *"Instead it was assumed that they move according to the relationship of layers D-E to the rest of the layers. I have therefore looked at layers A, B and C separately and turned the situation more towards drama for method-didactic reasons. I have therefore let the rich get richer which leads to more water consumption and generally more demand for water. Honestly speaking, that was my main motivation. Can be achieved without major effort."*
>
> Interview modeler O t3 45: "*Another problem was that the results were to a certain extent not dramatic enough for us. So we tried to manipulate it so that the results were somewhat more dramatic. The full simulation scenario did not therefore go as quickly as originally hoped. Because results were not as we would want them to be."*

Then, after *critical feedback* from the scenario group on the combined scenarios, perceiving the input assumptions on poverty as too dramatic, the four time series were further adapted. This led to narrowing down the *spread* quite considerably with respect to alternative developments of the social levels D&E, varying now between 45% ("increasing poverty) and 30% ("decreasing poverty") (cf. phase 5).

For more detailed illustrations of how quantification was realized in supposedly simple, yet complex cases such as the descriptor tariffs; and in cases, where no data on alternative future developments was available, as in the case of the descriptor poverty, and for their final translation into numerical input data, see Annex U.

7.1.5.5 Bundling i.e. definition of sets of input data (3c)

The third activity of the matching process, the bundling, consisted of the definition of sets of time series to be used as input data for simulation runs. This activity, in contrast to the foregoing ones, was a method-driven one in a double sense. First, CIB had an indirect but strong effect through the raw CIB scenario sets, which were used to structure the numerical input data sets. The modelers took up the CIB reference configurations and added the information on scenario composition regarding the ten quantified descriptors to their input data sheets. Every time series was labeled with the scenario it was used in; for an illustration, see Annex HH).[316] Second, the modelers wrote EXCEL routines to export these sets of time series automatically from the input-parameter sheet into LiWatool (technical integration through intermediary software). Thus, the selection of time series per scenario was technically solved in a rule-based and reproducible way**.** Still, for the selection of each scenario, LiWatool required that the user copy and paste the bundled input data corresponding to a specific scenario by hand from one EXCEL work sheet into another (with two mouse clicks). This introduced a potential source of error, see loop IV above and phase 4 below.

[316] The rules on scenario composition defined within this sheet were also checked by the scenario experts with regard to its consistency with the CIB scenario sets (cf. FN March 2012).

7.1.5.6 Overall conditions of matching

Overall, the matching required a lot of effort and used a lot of resources and competed for project resources with other project activities. The matching itself was not officially organized in the form of an extra work package, but was carried out as a side activity by the scenario experts and modelers, who invested a lot of resources into it, but who had, at times, other priorities (cf. interview scenario expert L t2, 100). These conditions were not optimal, but may have fostered pragmatic decisions. Due to the parallel nature of this work, it took about three years of at times intense desk research, meetings, interviews, workshops and countless emails. [317] The timing of the hybrid scenario process was such that the CIB analysis was completed by the end of 2011, when the definition of input data sets was still ongoing and was not finally achieved until May 2013. Most of the time series were thus constructed *after* the CIB analysis, where mostly only qualitative formulations of the D&V had been fixed by the scenario group and scenario experts (rather more than less definitely; for an exception, see loop III).

In addition, I had a particular perspective on the matching process and was in a double role. As one of the scenario experts, I played an active role in motivating for and facilitating of the matching process (especially in 2010–2012), e. g. by providing templates and organizing (virtual) workshops and in mediating between modelers and scenario experts. I was procedurally involved (and quite a lot), but tried to stay out of decisions on content. In 2013, I further influenced the process through consistency checks and then opted out of the process after the first version of brochure. Thus, I was *not* involved in the last phase of matching in April and May 2013 and the final version of the input data set. Overall, I personally experienced the matching as a muddling-through process, bringing together heterogeneous actors and needing to deal with unclear responsibilities, challenges of inter-, transdisciplinary and intercultural communication, learning by doing due to a lack of methodological guidance and experience, and insufficient data availability. This led to the search for pragmatic solutions and to some level of frustration. From my interviews, it became clear that modelers and scenario experts had shared this experience—as expressed by one modeler (interview O t3 43): *"I think that we would have to streamline a process like this more in future, we have all been suffering from it quite a lot."*

7.1.5.7 Products: numerical input data sets

During the matching process in the LiWa project, several versions of indicators and time series were defined and refined over time and bundled into sets of input data.[318] In the following, I consider

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[317] This duration also seemed to be self-enforced through issues of missing closure of the process with regard to new (status quo) data: the longer the process takes, the more new data is available, which means the process takes even longer to integrate this data, and then even newer data appears.

[318] For an example of the EXCEL input parameter sheet used by LiWatool, see Annex HH; for a comprehensive overview of all final quantifications, see Annex II.

mainly four central versions of the time series (and their sets) that were marking (interim) products of distinguishable phases of the matching process (in the following 'TS1-TS4').[319]

7.1.6 Zoom into phase 4 model building and simulation

The input data sets based on the raw CIB scenarios have been used for scenario simulation with the simulator LiWatool, resulting in the second half of the numerical scenarios. In this zoom into the methodology I ask, whether the CIB analysis or the combination with it played any direct or indirect role with regard to model building and simulation (beyond the definition of input data). Did some form of 'matching on level II', that is any comparison or adaptation between the numerical LiWatool model and the conceptual CIB model occur, and if yes, how was it methodologically designed? Table 25 gives an overview of the methodology of this phase that is roughly divided into model building (phase I and II)[320] and simulation (V1 and V2).

7.1.6.1 Model building and simulation

To analyze potential effects of CIB on simulation outputs, the broader context of activities in which the simulations are embedded needs to be considered. The definition of input data sets was analyzed in the preceding section. In this section, the modeling building and simulation are presented.

The simulator of the water infrastructure system of Lima, "LiWatool" was developed by modelers at ifak, Magdeburg. [321] This simulator provides a software platform based on material and resource flow analysis and uses linear and non-linear equation systems to calculate water volumes and qualities of drinking and waste water fluxes. These are represented with the help of so-called Sankey diagrams

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319 The *first (complete) time series* from resulting from the first phase of matching in the years 2010 and mainly 2011, used as input parameters for the first LiWatool simulations of the CIB scenarios (in the following **TS 1 first simulation**) (DOC Scenarioquantification _20120313).
The *interim time series*, resulting from refinements and corrections of the input parameters after the first simulation in the year 2012, (in the following ***TS 2 LOOP III***). (DOC Scenarioquantification_20121206).
The *interim* time series, resulting from matching *and integration* (seephase 5) activities in the year 2013. These input parameters have been underlying the *simulations* for the first version of the combined scenario brochure that then was discussed by the scenario-group (In the following **TS 3 integration**) (DOC Scenarioquantification_180313).
The *final time series* from resulting from matching and iteration (seephase 5) that were used as input data sets for the final LiWatool simulation of the LiWa scenarios for the combined scenario brochure (in the following ***TS 4 iteration***) (DOC Scenarioquantification _020513).

320 Please note that this description is very rough, since the model building needs to be divided into the programming of LiWatool, the simulator, which is in principle applicable to various empirical situations, and the specific empirical models representing the water system of the city of Lima. In this case, one detailed model (granularity on district level) was developed for the water company SEDAPAL, and a very coarse model 'Lima in one block' was developed for scenario simulation and policy evaluation for the entire city of Lima.

321 *Timing*: The construction of LiWatool had already begun during the pre-phase of the LiWa project, and continued throughout the main phase. Extensive research trips to Lima had been necessary to get access to relevant information and data of the water system. Only from March 2012 on was the model sufficiently supported by empirical data to allow simulation of the LiWa scenarios.

(Annex V). For scenario simulation, the empirical model Lima in one block was built, representing the water system of Lima in a comprehensive, but very much simplified form.[322] This empirical model Lima in one block covers the water system of Lima from the river runoff; over the preparation and distribution of drinking water for domestic and industrial consumption, as well as its use for irrigation in agriculture and further green areas; up to the collection and treatment of wastewaters and to their final discharge into the ocean. Central output indicators are overall consumption and overall supply of water and, centrally, their balance; income generated by tariffs; waste water quality; and energy used by the water system, for example.[323]

Overall, the construction of the LiWatool simulator was separated from the CIB scenario building; it was a closed-shop activity, to which only the modelers had full access. As far as I see, no explicit and systematic matching on level II occurred. No specific technique or arena was used or created to allow for a systematic and open comparison and adaptation of model structures (conceptual CIB vs. numerical LiWatool model). The building of the CIB matrix had been finished long before simulations were executed—thus, no adaptations of the inner structure of the CIB matrix in response to simulation occurred. Based on the evidence of this case study, I cannot judge to what degree the conceptual CIB model may have had an impact on the structure of the LiWatool simulator or of the empirical Lima in one block-model for scenario simulation. There is selected evidence for *some* form of matching on level II that occurred during the discussions between modelers and scenario experts. For instance, modelers and scenario experts had repeatedly talked about the issue of relevant model 'criteria' or model outputs,[324] and about how strictly to separate policies and scenarios.[325] Both issues

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322 Access: I had no direct or continuous access to model building or to the simulation. Especially the first was the modelers' task in close consultation with the water company, as the database of LiWatool was strongly dependent on their data. In consequence, the modeling process was in large part inaccessible to the scenario experts and to me. Similarly, the scenario simulation remained in large part a black box to me as to other externals. Despite having had training in the software, despite having access to the modeling software, and despite my and the modelers' efforts, I am far from understanding LiWatool's internal model assumptions—even if, theoretically, I understand that its mathematical equations are clear to those who can understand them. Therefore, I rely instead on my own experience as one of the scenario experts, observing model building and simulation from some distance, on personal communication with the modelers (including interviews t2–t3), and on the validation by key informants of my findings for this phase.

323 For more information on LiWatool, see http://www.lima-water.de/en/pp3.html; Schütze (2015), and Schütze/ Alex (2014).

324 See e. g. interview modeler O t3 31: "Also *interesting was, in my view, I had already asked about possible assessment criteria at least 2 years ago, did not get any and then thought up some myself. But there was still something for "oferta-demanda" criteria in recent weeks …My suggestion for next time would be get the criteria definition earlier and more clearly next time. […]"* and FN February 2013: 334 ff.

325 See e. g. interview modeler. O t3 31 "[…] *The division or connection between scenarios and measures was a little unclear to me. I would suggest next time making a more exact and sharper division in the scenario group in Peru, what belongs to what, i.e. what is scenario, what is action. Some measures are already in the scenarios… which was therefore difficult for me in the simulation in that, to put it bluntly, I was not able to simulate some activities because they were inconsistent with the scenario. Then again, I found your messages or those from expert L inconsistent. Recently, on 6th March, we simulated a chain of policies and expert L then said that these policies do not work at all in scenario A Although the same policy—chain in November was previously simulated by all of us at the round table and that was*

revealed that both actor groups have different understandings and definitions of *criteria* and of *scenarios* and that mutual understanding had to be developed first.[326] In addition, both groups had no comprehensive or deep understanding of what the others were doing, that is what LiWatool was able to do, or, respectively, how the CIB scenarios were conceived. Further hints on comparison and even adaptations of model structures relate to the issue of water consumption. Water consumption per capita was an issue covered by a CIB descriptor and also calculated by LiWatool (cf. issue of overlap between system representations). Therefore, scenario experts tried to understand the calculation by LiWatool, which in response was documented in verbal form by the modelers within the descriptor essay (see FN February 2013). Furthermore, effects of increasing tariffs on water consumption were an issue. In the CIB matrix it was assumed that increasing tariffs hinder increasing water consumption. LiWatool represented this relation through the use of price elasticity assumptions. This led to quite considerable effects on the simulation results. The plausibility of this numerical assumption was discussed several times among scenario experts, modelers and the issue expert (cf. e. g. FN WS tariffs II 20120606). Finally, LiWatool in its final version took up ideas also expressed through the CIB scenarios on future developments of green area, which had consequences for the model beyond the mere definition of model input (cf. e. g. FN Nov_Dec 2012).

To conclude, LiWatool building was carried out separately from the CIB. I assume that if CIB had any impact during this phase, then it was an indirect effect brought in through the scenario experts, and that it played out on the level of the empirical Lima in one block model, but not on the level of the software of the LiWatool simulator.

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obviously fine ... I am, I am unemotional, but one has to be clearer about what is consistent, what is allowed, and what is not. […]"

326 For more details on these two aspects, see Annex W.

Table 25: Overview of the methodology of modeling and simulation (LiWatool) (phases 2*and 4), elements with central impacts in bold and underlined (Lima Water)

Activity	Building LiWatool V1	Simulation phase I Spring 2012	Building LiWatool V2	Simulation Phase II Jan-May 2013	Matching level II
Objective	*How to build (what) simulator of the water infrastructure system of Lima? (One that is useful to local experts and that allows for simulations of the LiWa scenari-os?)*	*How to simulate the LiWa scenar-ios? What are interesting LiWatool outputs?*	*How to refine the simulator of the water infrastructure system of Lima? (Consider-ing new requirements to the simulator emerging during the project)*	*What output information does the simulation of the LiWa scenarios provide? How can the numerical scenarios match the ideas of the qualitative scenari-os?*	*Have the model structures of LiWatool and of the conceptu-al CIB model been compared / adapted to each other?*
Timing	2008-2012	March- April 2012 Need to specifiy criteria (LiWatool output) has been ex-pressed since since 2010	2011-2013 (also: continuous improvement)	Jan-May 2013	At very selected moments in 2012 and 2013
Methods	material and resource flow analy-sis, linear and non-linear equation systems	Test simulations with **<u>LiWatool V1</u>** guided by 'simulation stories'	New simulation kernel	Simulation with **<u>LiWatool V2</u>**	LiWatool (training) Close consultation between modelers and scenario experts LiWatool training also to stakeholders (e. g. Sedapal, LiWa partners, ANA-ALA)
Data	Information on past present and future developments of the wa-ter infrastructure in Lima, provid-ed by local experts and project experts	Output definition, Input data sets, internal model assumptions Parameter definitions	Refined and updated infor-mation on past present and future developments of the water infrastructure in Lima, provided by local experts and project experts	Refined and updated output definition, internal model as-sumptions, input data sets, parameter definition	CIB matrix Mental models of actors
Actors	**<u>Modelers</u>** Local and project experts	Modelers	**<u>Modelers</u>** Local and project experts	Modelers	**<u>Modelers, scenario experts</u>**, project experts
Conditions	Limited data availability, issues of data confidentiality; multiple aims of modeling and simulation exercise; limited disciplinary under-standing between modelers and other project partners; activities separated from scenario experts and scenario group and CIB				No (official) arena or tech-nique for 'matching level II'
Products	*1. LiWatool V1 simulator;* *MATLAB routines for plot genera-tion* *2. Models of Lima wa-ter/wastewater systems:* *a) In one block* *b) detailled*	*First simulations of scenarios* • *A, C and D (by modeler O) plus 'simulation stories'* • *B1 and B2 (modeler external 4 including "control tables" on simulation decisions* *Results plotted in automatic LiWatool figures*	*1. LiWatool V2simulator;* *plot generation and script-ing facilities integrated in LiWatool simulator* *2. Models of Lima water and wastewater systems:* *a) In one block* *b) detailled*	*Simulations for the integrated scenario brochure:* *SV Jan* *SV March* *SV Mai* *Output plots, numerical tables/ LiWatool figures (automatic)* *Input and output tables across scenarios*	*Selected moments of compari-son and mutual adaptations of CIB and LiWatool*

7.1.6.2 Products: LiWatool simulator and simulation results

The model building mainly resulted in two consecutive versions of LiWatool that are relevant for this analysis (LiWatool V1 and V2), the later based on a new simulation kernel and handed over to project partners.[327] The numerical input data sets resulting from phase 3 (matching on level I) were then used to simulate the LiWa scenarios with LiWatool. First simulation results were communicated in spring 201.[328] Then, for quite a while, no new (adapted) simulations were communicated, as the modelers were busy with the transfer to the new simulation kernel. Then a second round of simulations was made in spring 2013 that included data updates as well as new information on the infrastructure options, which were proposed by the water company.[329]

7.1.7 Zoom into phase 5 integration and iteration

The methodology of scenario integration and iteration can be analytically split into four sub-activities: The integration-related activities comprise 1) the preparation of the integrated scenarios among scenario experts and modelers and 2) the discussion of these with local stakeholders. The iteration-related activities comprise 3) the check of a newly proposed scenario C with CIB and 4) the final change of scenario C's content and structure (independent of the CIB matrix) within the narrative and numerical parts of the integrated scenarios.[330] Table 26 below gives an overview of the methodology of phase 5.

7.1.7.1 Integration

From January 2013 on, the different forms of the LiWa scenarios were integrated into a combined scenario brochure, containing the raw CIB scenarios as a scenario basis and further elaborated *integrated scenarios for all four scenario families,* each comprising narrative and numerical parts**.** CIB played an *indirect role* through *data generated with CIB* (mainly the scenario table) that was used to

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327 *LiWatool V1* representing 'Lima in one block' was used for first scenario simulations in March 2012 and was not accessible to non-modelers; *LiWatool V2* representing 'Lima in one block' had been transferred to a new simulation kernel in the summer of 2012 (cf. Schütze/Alex 2014). V2 was used for simulations for the integrated brochure (March and May 2013) and was handed over to project partners.

328 *First simulation round:*

- Scenarios A, C and D (March 2012, one day before the RT II by expert O), (based on TS 1 first simulation). (DOC Simulation_ScenA_C_D 20120314).
- Scenarios B1 and B2 (In April 2012 by external modeler 5) (DOC Simulation_ScenB1_B2_20120410).

329 *Second simulation round:*

- First new simulations provided in January 2013 (based *TS 2 LOOP III*) (in the following **SV January**).
- Simulations provided in March 2013 (based on *TS 3 Integration)* during the development of the combined scenario brochure, integrating latest data updates and SEDAPAL feedback (in the following **SV March**).
- Simulations provided in May 2013 (based on TS 4 Iteration) i.e. the simulations for the final version of combined brochure, after iteration (in the following **SV May**).

330 To analyze this phase, I mainly rely on the following sources of evidence: FN (January, February and March) 2013, Interviews t3 and the integrated scenario brochure V1 (March 2013) and V2 (May 2013) (DOC Scenario brochure 20130321 and DOC Scenario brochure final 201305).

pre-structure the scenario brochure. Each of the four scenario families was presented by four issue clusters ('governance, climate change, population and territory, water infrastructure') into which the qualitative descriptions of descriptor variants as well as the corresponding numerical formulations (simulation input) and some model output were sorted. CIB played an indirect role also through actors, namely through the scenario experts, mainly through myself: I had proposed the structure of the integrated scenarios and did several consistency checks of the integrated scenario with the CIB table and also constantly compared and integrated the narrative and numerical parts of the text. In response, the modelers adapted the numerical assumptions (inputs and outputs, cf. Loop IV) to the CIB assumptions and narrative assumptions (cf. FNs January and February 2013). The activity resulted in the scenario brochure V1 (21.03.2012), in its annex containing tables with an overview of simulation input and output across scenarios.

As to methods, this process was based on close cooperation and exchange between scenario experts and modelers, desk research, expert consultation with regard to refinements of input data and finally the scenario simulations with LiWatool. Refinements of input data and model building had to be finalized before simulation. In consequence, simulation results were provided just in time to integrate them into the first version of the integrated scenarios (V1), and to discuss them with local stakeholders during stakeholder workshops: A first small workshop was held at the water company, a second one with the entire scenario group.

Next to myself, pushing and organizing the workflow and structuring the presentation of the integrated scenarios, the modelers were central actors, supplying new input data as well as simulation results. At times, actors had different viewpoints with regard to the importance of the brochure compared with other project activities like the action plan. Viewpoints also differed with regard to the question of who the central target group would be (cf. FN February 2013: 538). Actors beyond the small scenario core team were included in this phase very late during two stakeholder workshops in March 2013. During one workshop at the water company, the stakeholders had fairly minor comments and a benevolent perspective on the integrated brochure (cf. FN March 2013: 158 ff.). In contrast, another workshop with the scenario group was marked by a big debate: Some members of the scenario group criticized several time series as being too extreme ('black or white'), assessed (supposedly their own!) scenario sample as being too negative and finally proposed to change scenario C into a more medium one, since such a scenario was perceived as missing from the rather black or white sample (cf. FN March 2013: 175 ff.). At this moment, my active participation stopped because of my maternity leave. Still, I was informed by my colleagues and through email traffic about the continuing activities.

7.1.7.2 Iteration

In response to stakeholder comments, two iterative activities took place. 'Iteration A': First, ScenarioWizard was used by the scenario experts in Germany to check whether and to what extent the newly proposed scenario C—now assuming a medium population growth and a constant poverty rate—was consistent with the original CIB matrix (no. 10). As it was quite inconsistent, the expert tested out, how assumptions stored in the CIB matrix might need to be changed, to turn scenario C into a consistent one. With this in mind, for testing purposes, one of the scenario experts constructed a renewed matrix (no. 11), introducing a new variant of descriptor A, 'government', namely a more medium one. The consistent configurations resulting from this test matrix produced a scenario sample quite different from the one established in the LiWa project until then.

'Iteration B': When learning this, the actors, namely scenario experts and modelers, decided not to go into a full iteration, that is to adapt the CIB matrix and to redo the scenario simulations, evaluations and documentation. This would have required important work including intense consultations with the scenario group, which was already tired from the long process. Instead, the new scenario C was integrated into the otherwise unchanged LiWa scenario sample—despite its inconsistency with CIB. Thus, actors opted for a loop that was quite easy to establish, namely to adapt the narrative texts and the LiWatool simulation input structure to the new scenario C and the simulation results within the integrated scenario presentation.

Overall, the central pieces of data during this phase were the raw CIB scenarios (tables), the storylines (short version) and the simulation input (TS V1) and output, building the basis for the first version of the integrated scenarios (V1) that was then presented to the stakeholders. At that moment, the stakeholders perceived the possibilities of future developments differently from the assumptions already integrated into the scenarios. Finally, for iteration, the CIB matrices (no. 10 and 11) and the new structure of scenario C were decisive.

With regard to conditions, the integration and iteration phase was carried out with especially restricted time resources: Simulation inputs and results were already very late so they were not fully understood, discussed or checked by actors beyond the modelers. Comments by the scenario group were collected only briefly before the final LiWa project event in Peru—thus there was no more capacity for time-consuming adaptations and integration activities.

Table 26: Overview of the methodology of scenario integration and iteration (phase 5), elements with central impacts in bold and underlined (Lima Water)

Activitiy	**Preparation of integrated scenarios**	**Discussion of integrated scenarios with stakeholders**	**Iteration A): Check of new scenario C in LiWa10cim**	**Iteration B): change of scenario C in narr. and num.**
Objective	*How to prepare a joint scenario product, presenting CIB scenarios, storylines and simulation results in an integrated way?*	*How are the integrated scenarios perceived (accepted/criticized) by local (internal) stakeholders?*	*Is the new scenario C consistent with the CIM/ How do we need to change the CIM to make it consistent?*	*How can new scenario C be translated into narr. and num. representations within the integrated brochure?*
Timing	January-March 2013 Aber hat doch eigentlich schon vorher begonnen	March 2013	April 2013	May 2013
Methods	Desk research, Expert consultation LiWatool (simulations: just in time) CIB indirectly through data and actors Comparison between and adaptation of narrative and numerical versions (including consistency checks with CIB table	Stakeholder Workshops	CIB	Storyline writing LiWatool simulation for new scenario C New numerical definition of Scenario C, resulted in need for redoing the related simulations
Data	Raw CIB scenarios (tables) Storylines (short version) Simulation input (TS V1 and output	Brochure V1	Matrix no 10 New scenario C	New TS V2 New internal structure of scenario C
Actors	<u>**HK**</u> pushing and organizing workflow and structuring narr. and num. elements /presentation ('shifting sides'). <u>**Modelers**</u> supplying new input data as well as simulation results ; modelers improving the simulator and output representation. Further scenario experts mainly occupied with other activities: action plan).	Scenario experts organize workshops. SEDAPAL: rather benevolent, minor comments. <u>**Scenario group**</u>: big debate, criticizing time series as to extreme, sample as too negative, propose change of scenario C.	<u>**Scenario experts**</u> (HK drops out of the project).	<u>**Modelers**</u> Scenario experts
Conditions	Limited time resources. Timing: simulation input and output ready so late, results can merely be understood and checked.		Restricted time resources: only few days before final LiWa project event in Peru.	
Products	*Integrated scenario brochure V1 (18.03.2013)* *Each scenario following the structure of 4 slightly renewed issue clusters*	*New scenario C (more moderate assumptions with regard to poverty and population growth); new input-data*	*New Scenario C is inconsistent with Matrix no 10, Proposal of possible Matrix no 11 decided against.*	*Final version of integrated scenario brochure V2 (May 2013)*

7.1.7.3 Products: integrated scenarios

The two central versions of the integrated scenarios are documented in the integrated scenario brochures.[331] For detailed characterizations, see Annex X.

7.1.8 Overall character: social organization, technical design and cognitive dimension

Taking a step back and reconsidering the overall methodology, the Lima Water case can be characterized as follows:[332]

7.1.8.1 Technical design: using CIB to construct scenarios that are translated and then simulated by LiWatool

Overall, in the Lima water case, the integrated scenario process was marked by *two central methods*, the CIB, which was applied in a workshop and group-modeling design to construct the raw CIB scenarios, and then by LiWatool, the newly constructed water infrastructure system simulator used to simulate these. Furthermore, close consultation and co-operation between modelers, scenario experts and issue experts was organized through multiple formal (interviews, workshops) and even more through informal techniques (meetings, emails etc.). These further techniques were particularly important during matching and integration.

7.1.8.2 Social organization: at times low inclusion and unclear responsibilities regarding the method combination

The *initiative* to carry out a combined scenario process came mainly from the scenario experts and modelers; the proposal to try out a pioneer CIB&S process came from the scenarios experts with their specific interest in the method CIB, an interest that I took up and reinforced. The process was fairly inclusive and transdisciplinary with regard to local stakeholders and experts, who were included in the 'qualitative side', providing mainly local knowledge (in their role as local expert) and to a certain degree also diverging perspectives (in their role as stakeholder). Exceptions were the CIB analysis and sampling, which were mainly in the hands of the scenario experts until the reappropriation of the scenario sample through the scenario group at the very end of the process. Overall, modelers were only weakly included in the qualitative side of the project, and the scenario experts scenario experts and scenario groups were only marginally included in the work of model building and simulation. Thus the qualitative and the quantitative activities remained rather separate, with clear-cut

[331] **V1 integration**, i.e. the first version of the brochure as discussed by the Peruvian Stakeholders (March 2013), based entirely on the *CIB* scenario table (see Annex EE).
V2 iteration, i.e. the final version as published on project website (URL: http://www.lima-water.de/documents/scenariobrochure.pdf), based on the adapted scenario table, see Annex FF.

[332] This characterization provides a reinterpretation of the results from all over section 7.1.

responsibilities. The scenario experts, together with the scenario group, were responsible for analyzing the CIB, constructing the raw scenario construction and writing the storyline; the modelers were responsible for building the LiWatool and for simulation.

With regard to the activities 'in between', mainly the matching and the integration, responsibilities were at times not clearly distributed. This resulted in mismatches between the distribution of tasks, support, abilities, power and time. In both 'combination activities', I took over the role of the combination person and facilitator, namely during the matching and during the redaction of the integrated scenarios. In the end, both activities were carried out by the scenario experts together with the modelers, resulting in co-constructed products. Overall, the integrated scenario process was supported by the scenario experts and modelers along with both project coordinators, and by the local water company.

7.1.8.3 Cognitive dimension: integration of qualitative scenarios and their quantitative reinterpretation and analysis

With regard to data, the integrated scenario methodology comprised the synthesis of inter- and transdisciplinary qualitative scenarios, based on the group model of the local stakeholders stored within the conceptual CIB model (impact network), which was in turn based on expert assessments. The resulting scenarios then were reappropriated twice: First, they were locally embedded and appropriated by the scenario group; second they were reinterpreted in a numerical way during matching by the modelers and issue experts (based on readily available data, research by the LiWa project and expert guesses) and numerically assessed through their simulation by LiWatool. Finally, on the level of scenarios, the qualitative and quantitative representations were integrated in the form of integrated scenarios. The combined scenario process was expected to have impacts on mental models and system understandings of actors as well as—even if very implicitly and selectively—on comparisons and adaptations of the numerical LiWatool and the qualitative CIB.

7.1.8.4 Conditions

Overall, the Lima Water case was a pioneer application of CIB&S under difficult conditions: Competencies with regard to the methods used was missing with regard to the following methods:

1. CIB, among some of the scenario experts and modelers as well as among most members of the scenario group.
2. Numerical modeling and simulation and specifically LiWatool.
3. Hybrid scenario processes and more specifically CIB&S processes.

Furthermore, *time and money*, responsibilities and the *mandate* of the integrated scenario process was at times unclear, too: What priority and weight does it have within the project? Who needs what kind of scenario products and what for? Activities and decisions were, over time, pragmatically adapted to project realities. Necessary learning processes were presumably also due to the *pioneer nature* of the application of CIB within integrated scenario methodologies.

7.2 Characterizing the form of combination of CIB &S: CIB as steersman of a combined scenario process.

The specific form in which CIB was used in combination with the simulator LiWatool in the Lima Water case can be characterized as follows. Table 28 below gives an overview (in section 7.2.4).[333]

7.2.1 System representations: CIB synthesizes central factors affecting the water futures of Lima; LiWatool analyzes the technical water system embedded in these in a numerical way

In the form of a qualitative group model, representing the mental models of local Peruvian stakeholders, CIB represents the socio-technical-environmental water system of Lima. The raw CIB scenarios indicate possible future developments of this overall system. LiWatool, using a numerical simulator and the model of Lima in one block, represents the water system of Lima, with a main focus on the technical water infrastructure of the megacity. LiWatool takes over the future uncertainty of the overall socio-technical-environmental water system. This is done mainly in the form of numerical, exogenous parameters; it simulates the scenarios and calculates additional output information, like the total water supply and demand (and their balance) as well as evaluation criteria on the future state of the water system (e. g. income by tariffs). Furthermore, it visualizes (water) fluxes within the system over time (dynamics) and provides figures on model input and output.

With regard to the division of labor, qualitative and social-science aspects as well as future context uncertainty are represented by the CIB (as for example future developments of political and institutional issues). Quantitative and water infrastructure related aspects as well as system consequences of different future contexts (for example the quantity and quality of water available over time) are dealt with by LiWatool. Still, the technical and environmental aspects are represented by the CIB, too, albeit in a simplified form. The CIB has a rather static approach focusing on the 2040 scenarios and the paths leading to these; LiWatool considers developments over time and provides information for every chosen year.

CIB and LiWatool simulator (model Lima) both cover the same *geographical* scope, namely Lima Metropolitana. But both have different *thematic* scopes, CIB covers different domains, including governance, population and territory. It also covers technical water infrastructure and climate change, though with low granularity and little detail, by 13 descriptors with two to four variants each. In con-

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333 This characterization is based on process documents and observations and was validated by two key stakeholders.

trast, LiWatool more specifically covers mainly the technical water infrastructure but on a higher level of granularity and detail.

The two systems have considerable overlap, albeit predominantly at their shared borders: The majority of the CIB descriptors (CIB system elements) is used by LiWatool in the form of (quantified) framework assumptions (input data, introducing assumptions on context developments into the model),[334] one CIB descriptor corresponds to a LiWatool output (water consumption per capita per day).

7.2.2 Positions: CIB first

With regard to *timing*, the conceptual CIB model and the mathematical simulator LiWatool as well as the corresponding model for Lima were all newly developed simultaneously during the LiWa project. The CIB raw scenarios precede and supply the storyline writing, the matching and the simulation. The LiWatool model for Lima as well as the matching phase were both completed during the spring of 2013 (the project ended in May 2013), see Table 27.

Table 27: Effective timing of the CIB&S phases, rough overview (Lima Water)

My presentation, based on observation. For the initial timeline of project cf. DOC LiWa_ proposal 2007: p. 33-
Legend: dark grey: main activity, light grey side activity.-

		2008	2009	2010	2011	2012	2013
1) Framing and design							
2 *Simulator building LiWatool and model setup and refinement of models for Lima water and wastewater system							
2* Climate downscaling and hydrological modeling							
2 CIB scenario construction	2a) Selection and definition of D&V						
	2b) Cross-impact assessment						
	2c) Selection and analysis of consistent scenarios						
3) Matching							
3*) Storyline writing							
4) LiWatool simulation of CIB scenarios							
5) Integration and iteration							
6) Usage (by external actors)							

Considering methods, CIB *dominated and steered* the entire combined scenario construction process content-wise and with regard to the structure of the individual scenarios and the scenarios sample. This holds true for the raw CIB scenarios and for the storylines—the numerical scenarios were co-constructed by CIB *and* LiWatool: The first half of them was structured by CIB, but content-wise oriented at LiWatool indicator/ data needs and the second half of the numerical scenarios was calculated by LiWatool alone.

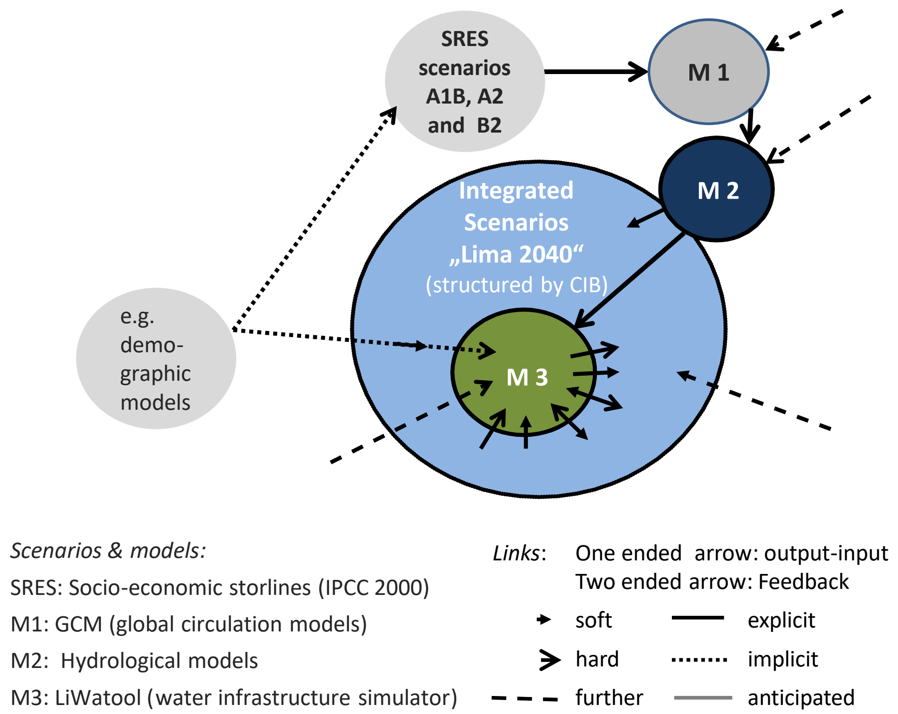
334 9 out of 13 CIB descriptors are 'coupling descriptors' (some only partially, some in more detail, see section 7.4) and used as model input by LiWatool (social, technical and environmental issues). Political and institutional aspects only covered by CIB.

Considering *actors*, the construction of raw scenarios and of the narrative storylines was dominated by the scenario experts and the scenario group. The numerical input data sets were co-constructed by scenario experts and modelers. Beyond the definition of input data sets strongly influenced by CIB and the scenario experts, constructing the LiWatool model and running its simulations laid (almost entirely) in the hands of the modelers.

7.2.3 Links: output-input coupling from CIB to LiWatool

Figure 24 shows the links between the different scenarios and models used in the Lima Water case.

Figure 24: Form of combination of CIB and numerical models, focus on the links (Lima Water)



In the center of this visualization of the linkages, I chose not to put the CIB as a conceptual model, but the integrated scenarios 2040 (that were structured mainly by the CIB raw scenarios) as most coupling between CIB and LiWatool happened *on the level of scenarios.* In addition to the CIB and LiWatool, the supply-modelling (M1 and M2) is added. In the following, the coupling mainly between CIB structured scenarios and LiWatool and back from LiWatool to the quali-quantitative integrated scenarios is described.

First**,** there is a form of *hard* output-input coupling of CIB with LiWatool through the raw CIB scenari-os, translated into numerical input data and used for scenario simulation. They are automatically read out through additional software.

Second**,** there is *soft* coupling of numerical scenarios with qualitative storylines in the form of inte-grated scenarios**.** Simulation results are fed back into the integrated brochure. This has two effects on the linkage: First, the simulation results complement the combined scenario brochure with simulation outputs and precise raw CIB scenarios and storylines through numerically defined inputs and outputs. Second, the simulation results are embedded again in their qualitative context assumptions (e. g. on governance structures). These had become invisible and at times not conscious during matching, even if the silent and indirect coupling of the numerical input data with the qualitative, non-coupled descriptors of the CIB remained through their link within the CIB.[335]

Third, there are different types of *output-input* links between further supply models, the CIB and LiWatool**.** For instance, they are linked to the hydrological modelling of the LiWa project and to other forms of models on, e. g., tariffs or green area from inside the project, and to other models from outside the project, e. g. to demographic models. Behind, meaning at the front-end of, these supply models, there are further models and scenario assumptions. In the figure above, this is illustrated in for the case of the hydrological modeling, which is input-output linked to different GCM which in turn chose framework assumptions based on the IPCC SRES storylines.

As to *Iteration*, during the process, feedback from LiWatool back to the CIB occurred. These were described above as Loop III from the matching on level I to the definition of the D&V and as loop IV from the simulation to the matching. Finally, all forms of scenarios were adjusted to the newly defined scenario C in the form of 'iteration B'—but no full iteration, in the sense of SAS, including the change of the structures of the CIB matrix, occurred.

7.2.4 Overall: form of combination and function of CIB

Overall, the form of using CIB within a combined scenario methodology in the Lima Water case can be characterized as *CIB as a steersman of a combined scenario process*. CIB defined content and structure for all forms of scenarios, with the numerical model co-contributing to the numerical scenarios. Still, the combination mainly occurred on the level of scenarios and not on the level of underlying models, as no systematic form of matching on level II and no full iteration took place.

[335] Remember that "the purely qualitative (and at first sight uncoupled) scenario factors of the CIB scenarios, indirectly also act onto the model –and even more indirectly on the model output, too—as they are interrelated (within the CI-matrix) with the other, more directly coupled factors." (Weimer-Jehle et al. 2016).

Table 28: Form of combination of CIB with numerical (simulation) models: CIB as a steersman of a combined scenario process (Lima Water)

Dimension	Operationalization	Lima Water
System representation of each component How do the different system representations look like?	**Division of labor** between CIB and the model(s); qualitative vs. quantitative representation.	**CIB** represents all factors assumed by the scenario group to affect Lima's water futures, including qualitative and social-science aspects (future uncertainty) **LiWatool** represents quantitative and water infrastructure related aspects and analyzes system consequences of different future context.
	Scope (also: What is in- what is outside? endogenous vs. exogenous?) **and granularity.**	**Shared geographical scope: Lima Metropolitana** **Diverging thematic scopes:** CIB: futures of the socio-technical- environmental water system with very low granularity. LiWatool: technical water infrastructure system with higher granularity.
	Overlap between the system representations.	**Overlap considerable:** N= 9 out of 13 CIB descriptors are coupling descriptors used as model input by LiWatool (social, technical and environmental issues, political and institutional aspects only covered by CIB). *Water consumption per capita per day* is at the same time one of the CIB descriptors and calculated by LiWatool (output).
Position of both components What role do both component play with regard to each other and in the overall process?	**Timing**: What comes first?	CIB and LiWatool were **both newly constructed in parallel** during the project, **CIB was pre-ceding the** (storyline writing, the matching and the) **simulation.**
	Dominance/ structuring the process/ central **benchmark** for adaptations.	**CIB and the scenario experts structured the entire scenario process** with regard to structure and content, exception: **LiWatool and modelers with final say on numerical content of scenarios** (with regard to both input data sets and simulation results- scenario structure defined by CIB!)
Link between the components How are CIB and model(s) linked to each other?	Type and level of **coupling.**	**Hard output-input coupling of CIB with LiWatool** through raw scenarios, translated into numerical input data and used for scenario simulation. **Implicit and indirect** coupling of LiWatool simulations with purely **qualitative** CIB descriptors. **Soft coupling of numerical scenarios with qualitative storylines** in the form of i**ntegrated scenarios** (level of scenarios).
	Iteration.	**Feedback between CIB and LiWatool in the form of loops (II and IV)** (bi-directional coupling) **and iteration B** (adjustment of all forms of scenarios to newly defined scenario C), **but no full iteration in the sense of SAS adapting CIB structures** (decided against).

7.3 Scenario traceability: Assessments and interpretation of effects

Scenario traceability was analyzed phase by phase through the methodology of the Lima Water case. First, for each phase, the degree of scenario traceability is assessed, based on the perceptions of the actors of the Lima Water case. Results are in the following summarized as traceability assessments. Second, possible reasons within the methodology are provided that explain the traceability perceptions and assessments of the specific phases and scenario products. I discern between direct and indirect (propagated) effects of CIB and effects of other elements of the methodology as further methods, actors and data. These results are summarized as interpretation of effects. For brevity and readability, only a few original statements are included in this summary.

7.3.1 Traceability of the raw CIB scenarios (phase 2)

7.3.1.1 Summary traceability assessments[336]

Table 29 gives a very brief overview of the overall traceability assessments of the raw CIB scenarios.

Table 29: Summary of scenario traceability of phase 2, construction of raw CIB scenarios (Lima Water)

	Was the CIB method perceived as comprehensible? /was it understood?	Did scenario assumptions become accessible and explicit during the qualitative scenario construction process and in the resulting raw CIB scenarios?		Were procedures of scenario composition and selection of scenario sample transparent?
		On future developments	On interrelations	
Overall assessment	Difficult, even for the scenario group members.	Given.	Explicitness of assumptions on interrelations given to process internals only.	Even for internals only partially given, rather opaque for externals.

Overall, CIB was perceived as a rather difficult method, even for internals.[337] Understanding CIB fully was perceived as not being easy, a special difficulty was how to fill in, read and use the matrix (impact assessment: direct impacts only, direction of impact). At least some of the participants had to take a hurdle to apply the CIB correctly,[338] especially during the repetitive exercise.[339] In addition, the required standardization convention was perceived by some as a *“straightjacket”* (interview scenario

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336 Results are summarized across actor groups and across sources of evidence.

337 For a typical statement, consider scenario-group member expert I (t3 58):*“It’s true, the CIB analysis was quite… was the most tedious and most difficult step. But I think, the active partners of the scenario-group, we all understand—or at least at the time of the analysis, understood the logic of the matrix, the impacts and how to analyze it, I don’t know if you ask all of us now… But at that time, everybody finally had an idea of the mechanism of CIB.”*

338 See e. g. Interview scenario group member G (t1 55): *“One of the most frequent problems with the impact assessment was, that sometimes we confounded, whether one descriptor impacts the other or whether the second impacts the first one. It’s sometimes difficult; especially when the discussion lasts for long, it seems that the brain is getting a little tired then.”*

339 See e. g. interviews scenario group member G (t1 71): “This is, of course, not easy. One would attempt, I suppose you would attempt to make it as easy as possible, but as there are so many factors, so many descriptors, it finally becomes a little complex [...]”. And J (t1 39, my emphasis): “Overall, the method was very particpatory, interesting – and tedious because of all the numbers [i.e. the impact assessment].”

group member expert N t1: 46, 76 ff.),[340] which might have hindered the acceptance of the method.[341]

For those who did not participate during the cross-impact assessment, is was particularly difficult to access the information within the matrix. Even internals (scenario group members as well as some internal modelers) had a vague understanding of the CIB consistency logic (i.e. its balance algorithm)—but no full understanding of CIB (cf. e. g. modeler Q t2 58 ff.). Finally, the usage of the ScenarioWizard software remained a black box for some members of the scenario group, despite training sessions.[342]

Assumptions on future developments of raw CIB scenarios were perceived as explicit and accessible by almost all actors (cf.e. g. interviews M t1 91, L t 2 190), despite some language issues (as for example imprecise definitions or sub-optimal translations) (cf. e. g. interview scenario group member G t2 45 ff.). Still, the lack of precise numerical definitions was seen as limiting traceability, especially by the modelers (cf. e. g. FN Ifak 20120427: 68 ff.).

Assumptions on *interrelations* of raw CIB scenarios were perceived as being explicit and accessible in the matrix (cf. e.g interview scenario group member I t3 69: "*The matrix is central with this regard.",* and scenario expert L t2 193 ff.).[343] Still, the matrix was not accessible and comprehensible to all, as not to external stakeholders and not to the external modelers (cf. e. g. interview scenario expert M t1 70, M t2 195). Furthermore, assumptions on interrelations disappeared again, when the raw CIB scenario(s) (sample) were presented in the form of the CIB scenario table. In this form of the raw CIB scenarios, interrelations are not perceived as visible anymore.[344]

Transparency of scenario composition and selection of sample were not automatically achieved, and not given for all actors. This was the case neither for all of the scenario experts (cf. FN January 2012: 51-63), nor for the modelers (e. g. interview O t2 225) as both groups perceived a tension between

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340 In the same lines, interview scenario group member G (t1 58): "But we were told that the program required the sum to be zero. This was difficult to understand and might have biased some of the attributed [impact] values." Cf. also K t1 54 and 108: "A burdensome corset."

341 See e. g.. interviews with scenario experts M t1 64, 100 and L t1 70.

342 See e. g. interviews with scenario group member N t1 96, 102 and N t3 60.

343 Still, most members of the scenario group as well as some of the scenario experts (cf. L t1 55) regretted that much of the content of the discussions becomes not easily traceable or even untraceable in form of impact assessements expressed in numbers, for an exemplary statement, see e. g. Interview scenario group member K (t1 75): *"With the numbers, we have lost much of the content of our discussion, including the negotiations that took place there."*

344 See e. g. interviews with scenario experts M t1 142, L t2 76 and with scenario group members K t1 98, 126, N t 1 89.

the formal justifications through the CIB algorithm on the one hand and the subjective elements during sampling on the other hand. The same applied to some scenario group members and externals.[345]

In sum, the perceived scenario traceability during phase 2 is rather medium to low, the explicitness on assumptions on future developments alone is and remains high for the raw CIB scenarios—for internal, and as evidence suggest, also for external actors.

7.3.1.2 Interpretation: effects of CIB vs. other elements of the methodology

The overall rather medium to poor traceability assessment of the CIB scenario construction phase can be linked to the characteristics of the CIB itself as well as to the social organization, technical design and cognitive dimension of this phase.

Understanding CIB is a precondition of traceability effects—but this condition is not fully ensured despite explication, facilitation and training

A major reason for this mixed to poor result with regard to traceability seems to be that CIB has to be understood to enable its user to benefit from its (theoretical) traceability effects. This condition has only partially been fulfilled. Some of the CIB properties (impact assessment, the standardization convention, the balance algorithm and scenario software) were sources of non-, partial or misunderstanding(s) of the CIB method itself—despite explication, facilitation and software training. These further methods seem to have not been sufficient to ensure a good comprehension of CIB among the relevant actors (especially among the local experts and stakeholders, the members of the scenario group and especially among external experts) of the Lima Water case.

Ambivalent scenario traceability effects through the use of the CIB scenario-table

The CIB analysis itself has strongly contributed to the traceability of assumptions on future developments and on interrelations, at least while the process was ongoing, for instance during Loop I, when D&V were sharpened again during the impact assessments. Still, assumptions on interrelations have soon been covered up again. This happened already during the CIB analysis, after the scenario composition and sampling, resulting in the CIB scenario table**.** This scenario table seems to have played an important double role for scenario traceability: On the one hand, it rendered the scenario sample and assumptions on future developments of the individual scenarios very explicit and visible, even to externals. On the other hand, the scenario table covered the underlying assumptions on interrelations again and, e. g., does not explain, why strongly diverging scenarios assume identical descriptor variants (e. g. with regard to water consumption per capita)—namely for very different reasons that are stored in the matrix.

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[345] See with regard to scenario-group members e. g. interviews e. g. Lt 1 88, H t1 52, with regard to externals interview extern modeler 5: 131 ff.

Limited inclusion of actors into the CIB analysis, especially into scenario sampling, hindered traceability

Furthermore, and this concerns the inclusion of actors, modelers were not actively included in the CIB scenario construction and the scenario group was only rather symbolically (through the software trainings) included in the composition of scenarios and the selection of a scenario sample. Especially this last step of the CIB was dominated by the scenario experts, who took the decisions with regard to scenario composition, sampling and scenario interpretation that were in part going beyond the consistency logic of CIB. These subjective decisions did not become transparent to the other actors of the process. Overall, the transparency of the sampling was heavily reduced as the sampling had been done by a few actors only, namely by the CIB scenario experts.

Language, data and documentation issues hindered scenario traceability

Finally, there are hints that also data issues contributed to the medium level of scenario traceability. Main problems were:

a) *Misunderstandings of short titles* of the D&V due to their shortness, to language issues and to diverging system perception;[346]
b) *Imprecise definitions* of the D&V presumably allowed an apparent *consensus* within the scenario group. But this hindered precision, also during the impact assessment, which in part was based on imprecise—but 'consensual'—D &V definitions;
c) *Missing (access to) documentation*, for instance to the descriptor essays, which have not been available to scenario group until March 2012 (RT II).

7.3.2 Traceability of the storylines (phase 3*)

7.3.2.1 Summary traceability assessments[347]

Table 30 gives a very brief overview of the overall traceability assessments of the storylines. Overall*,* different actors agreed that there is *a certain accessibility to and explicitness of assumptions on future developments* within the storylines, especially within the long ones.[348] But at the same time, and

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346 Meaning' behind short titles of descriptor developments is not self-explaining, even if these already define numerical values (E. g. tariffs, demography) as scenario-expert L states (interview t3 37): *"In the tables, the problem is reflected in the short headings which do not reflect the actual understandings and definitions concealing many non-trivial decisions that someone of course had to make. We might have done this first among ourselves when presenting. You would then end up with a thick ear, to a certain extent, as was the case yesterday. Perhaps we are not always so well prepared, what we 'actually' mean in the long version, if we only use short keyword titles such as 'probeza' [poverty]."*

347 Results are summarized across actor groups and across sources of evidence.

348 See for example scenario group member H (interview t2 48): "In the scenario group, we have been working on the short storylines. Clearly, you cannot integrate all the calculations, which are behind, inside these stories. But yes, overall, they are clear and comprehensible. At least, [with regard to the question whether] there is high population growth, strong governance or not…", see also interveiw scenario group member G t2 46.

this can be considered a counter-effect, the storyline texts were perceived as rather technical and dry, as they were overall following the CIB descriptor structure (cf. e. g. M t2 35). Even if in contrast to the matrix, they were clustered into four thematic blocks, they were perceived as not easily readable and as being suitable rather for expert target groups than for the general public (ibid.). On the opposite, *assumptions on interrelations* were not perceived as adequately represented in neither of both textual versions, especially not in the short versions of storylines. [349] The *construction process* behind the storylines and their *sampling*, as well as and the method used are assessed as not transparent or clear to externals. [350]

Table 30: Summary of scenario traceability of phase 3*, storyline writing (Lima Water)

	Were scenario assumptions accessible and explicit during the storyline writing process and in the resulting storylines?		**Were procedures of scenario composition and selection of scenario sample transparent?**
	On future developments	**On interrelations**	
Overall assessment	Rather given.	Not given.	Not perceived by externals.

Further explication and documentation are seen as necessary. Furthermore, from the internals' view, the storylines do not reflect the work and effort of the scenario group that are behind—and especially not with regard to the impact assessments (cf. e. g. H t2 30). This, following the interviewees, also makes the storylines vulnerable to external critique (cf. G t2 39 ff.)

7.3.2.2 Interpretation: effects of CIB vs. other elements of the methodology

Overall, the high traceability of assumptions on future developments of the raw CIB scenarios seems to have propagated into the storylines—and the difficulties with regard to the other dimensions of traceability, too.

The (internal) use of CIB generated data supported scenario traceability of storylines—for internals

CIB had, through CIB products, a strong indirect impact of the scenario writing in general (cf. phase 3* above) and also on the traceability of scenario assumptions: During writing of the long version of storylines, the scenario table, the protocol and diagrams, and during the writing of the short versions, the table and the long versions played an important pre-structuring and content-providing role. This supported the propagation of very explicit assumptions on future developments into the storylines. Assumptions on interrelations were also handed down through the CIB impact diagrams and the CIB matrix. But these were used as internal products for the redaction of the long version

[349] See e. g.interview scenario-expert M t2 127, 181-186 and FN March 2012: 388.

[350] See e. g. in interview scneario group member G (t2, 39): "If you do not participate in the process, you could think that these scenarios had been just fabricated like that yesterday." , see also Interveiws H t2 30, 48; extern t2 27 ff.

only. The short version was written by someone without deep understanding and without access to the CIB method, its software and products. Thus, understanding CIB remains a precondition to benefit from its effects: The CIB matrix, in theory supporting the traceability of assumptions on interrelations and of the scenario sample was only helpful to those, who understood CIB and had access to the material.

Linear character and limits of length of storyline texts hindered traceable presentation of assumptions on interrelations

During storyline writing, tensions arouse between the three aims of making assumptions on interrelations explicit, the need for linear text (vs. CIB scenarios in the form of interrelated and quite complex constellations of the CIB network) and to keep the length of a text to a readable level. Missing text on interrelations was especially an issue in case of counterintuitive phenomena within a scenario (e. g. why scenarios with a private water company at the same time assumed increasing network losses). The clustering of issues into thematic blocks (especially visible in the long version, and later, albeit with slightly different blocks in the integrated scenario versions, see phase 5) might have increased the accessibility of the storylines, especially to externals.

Subjective bias through storyline authors on representation of interrelations and on sample

In both phases, storyline writing was rather an individual than a group activity. In addition, several interviewees suspected that whoever writes the storylines, always introduces subjective bias. This subjective bias mainly relates to the choice of a specific order of the text (see linearity issue) and to the selection of interrelations that are (not) described. Both issues hinder the traceability of assumptions on interrelations. Furthermore, during the storyline writing phase, additional subjective bias of *scenario experts* was introduced into the scenario sampling through their selection of reference scenarios and through their simplification of the scenario sample (first simplification).

Descriptor essays and external comments were increasing storyline traceability

Beyond CIB generated data, two other elements of data positively impacted scenario traceability during storyline writing: First, the descriptor essays were helpful for scenario experts during writing of the long versions of storylines and allowed to include definitions of descriptors going beyond short titles. However, and this is the downside, these descriptor essays have not been accessible for the initial author of the short versions. Second, comments by external experts and stakeholders had a fostering impact on scenario traceability too, as they were showing, what phenomena were perceived as counter-intuitive. These comments pointed at those assumptions on interrelations that essentially would need to be made more explicit—and led to sharpening the textual justification of some of the impact assessments.

7.3.3 Traceability of the numerical input data sets (phase 3)

7.3.3.1 Summary traceability assessments

Table 31 gives a brief overview of the overall traceability assessments of the matching and the resulting numerical input data sets (first half of the numerical scenarios).

Table 31: Summary of scenario traceability of phase 3, matching (Lima Water)

	Did scenario assumptions remain or become explicit and accessible during the matching and in the resulting numerical input data sets (first half of numerical scenarios)?		**Transparency of procedures of scenario composition and sampling?**
	on future developments	**on interrelations**	
Overall assessment	Assumptions on future developments rather explicit, matching reveals some more assumptions and adds further implicit assumptions.	Generally, interrelations covered during matching, except for specific instances as loop III, e. g.	Non-transparencies handed down, bundling is not much of an issue, matching itself not transparent.

Overall, the *explicitness of assumptions on future developments* propagated rather well from the raw CIB scenarios to the numerical input data sets. In addition, the matching phase had some specific properties that, on the one hand, fostered the explicitness of assumptions on future developments beyond CIB , but that, on the other hand, it also introduced further rather implicit or not sufficiently documented assumptions into the time series (cf. interviews extern modeler 5 t2 130, scenario expert M t2 79). In parallel, it seems that the non-transparencies of the prior phase were handed down, too.

During matching, *explicitness on future developments* was given with regard to those D&V that were translated into numerical input. Furthermore, the matching process itself seems to have supported the explicitness of assumptions, too. During the matching, actors needed to develop a shared system understanding and shared language was necessary for mutual comprehension—this helped to overcome (prior) misunderstandings. Matching revealed assumptions in a sharper way than in prior phases (through, e. g., forcing for precise verbal definitions to select indicators or through status quo definitions),[351] uncovered normative biases as well as at times weak consensus hidden behind qualitative formulations (cf. e. g. interview L t2 46). Expert validation, where possible, forced to reveal assumption more precisely than before (cf. FN January 2011, FN WS tariffs II 20120606). Still, those D&V that remained qualitative were clearly in the background during matching—and their silent (!) interrelations with the quantified ones were not explicitly taken into account and at times even a little forgotten, as they were considered as not being directly relevant for LiWatool.[352]

[351] See interviews scenario expert L t2 151, modeler O t2 258 and FN March 2012: 428.

[352] See interview with the modeler O (t3 94, my emphasis): *"[…] Finally, it's the time series that matter. Everything else is, for my work, not irrelevant, but not directly relevant. I have to now, how do the numerical time series look like. That is the most important to me.* ***The*** *prose around it is not so important to me […]."* See also interview scenario expert L t3 93.

Matching also introduced *further (implicit or not sufficiently well documented) assumptions* that hindered the traceability of assumptions on future developments, as matching required further (not necessarily explicit) assumptions (e. g. behind data, extra assumptions during translation etc.). This happened in response to the degrees of freedom of the translation, which was perceived as quite considerable by the modelers. As one of the external modeler commented, sources and procedures behind (interim versions of) the time series were not transparent to him.

Almost all *assumptions on interrelations* were at almost all times covered during matching. This type of scenario assumptions was not in the foreground during matching. Exceptions were specific (and rare) moments, as during loop III, when assumptions on interrelations became relevant to justify quantifications (see the example of tariffs, e. g.).

Similarly, *scenario composition and sampling* were not much of an issue during this phase. The bundling, i.e. the definition of input data *sets* was automatized through the intermediary software, but remained on the same low degree of traceability as in the prior phases.

In addition, matching is perceived as being fully traceably only for very internals, that is for the modelers. Even scenario experts did perceive the matching as not fully transparent regarding the choice of indicators that were justified by model needs, for instance. In addition, the definitions of inputs (and outputs) were traceable for internal scenario expert with the help of detailed explications by the modelers only.

7.3.3.2 Interpretation: effects of CIB vs. other elements of the methodology

Overall, scenario traceability propagated to the numerical input data sets through second order effects of CIB, the matching itself had further promoting and hindering effects on scenario traceability.

The use of CIB generated data and the work by CIB-advocates had fostering impacts on scenario traceability

CIB had indirect impacts on the scenario traceability of assumptions on future developments and of the scenario sample through CIB data, mainly the use of the scenario table, and actors, as modelers did orient their time series at the CIB scenario table and scenario experts acted as advocates of CIB. For instance, these CIB advocates also used the matrix to reconstruct the reasoning of the scenario group and to match it with the modelers and issue experts’ system understanding—at least at very specific and rare moments. This occurred during Loop III, when reflection on interrelations becomes necessary during quantification, and during consistency checks by me, when assumptions on interrelation were uncovered again.

Matching techniques: the necessary reappropriation of assumptions on future developments by actors newly entering the scenario process

Matching was a muddling through process that used all sorts of methods and techniques to find pragmatic and viable solutions. Traceability of assumptions on future development had to be reproduced through the reappropriation, discussion and expert validation of these assumptions through modelers and issue experts. These actors were newly entering the scenario process at this stage. To be able to effectively co-operate by bringing CIB and LiWatool together, modelers and CIB scenario experts perceived a need to develop a shared system understanding comprising a common language to communicate about the common issues and also on the shared methodology (what is a *scenario*, what are *criteria*, what are *indicators* etc.). This was supported through small and informal expert workshops bringing these actors together with the scenario experts. In the newly built input data software for automatic readout, the sample structure of input data sets was transparent in theory, but not for externals either, see phase 4 simulation.

Matching as a closed shop activity (missing inclusion)

During matching, decisions were taken in very small and closed groups of actors. Often, these comprised not more than one scenario expert and one modeler. In the most extreme cases, final decisions were taken by one modeler alone. The modelers, even if orienting the time series at the CIB table, always considered LiWatool requirements first. Many of the decisions on time series were either intuitive, model- or data-driven, without making this explicit or without sufficient documentation. In parallel, the scenario experts are the ones, who pragmatically and all alone decide on the second simplification of the scenario sample, too. The scenario group as a whole was not included during matching activities—individual members were included in the role of local issue experts. This might explain, why matching is perceived as transparent only for 'very internals'.[353]

Data issues and documentation hinder scenario traceability during matching

During this phase, the descriptor essays (DE) played an ambivalent role. On the one hand, they were necessary and useful for modelers and issue experts to gain a shared understanding with the scenario group. On the other hand, the DE have never been finished nor published and the latest decisions on quantifications have not been documented inside either. This hindered adequate and accessible verbal documentation and justification of final time series and of assumptions on interrelations—which otherwise might have even better supported the different actors in developing a joint under-

353 Evidence suggests that in consequence, the *limited understanding of the hybrid scenario methodology* and of matching phase has hindered more active participation of the scenario-group during the matching and has made task more difficult for scenario experts and modelers, too (cf. interview expert N t3 39).

standing.[354] Furthermore, there were multiple issues of unclear data. Missing and limited data required ad hoc estimations; and in cases when data (e. g. time series) were available, it often came from unclear sources and carried unclear (implicit) assumptions on interrelations with it. A final problem was confidential data.[355]

Scarce resources, duration, timing and indirect cognitive integration hindered a higher level of scenario traceability

Matching took place under very limited resources for expert validation and especially for sound and direct documentation of qualitative and quantitative assumptions. Due to the sheer duration of the matching process, scenario experts and modelers somewhat forgot, what assumptions they once had made when building the time series. As to timing, the matching had started, when the CIB was almost finished. In consequence, actors, who had not been included in the CIB (modelers and issue-experts), first needed to (ex post) reappropriate the scenarios. Thus, during matching, an indirect form of cognitive integration between the system perspective of the modelers and the system perspective of the scenario group occurred that was mediated by the scenario experts. The impact of the actors newly coming into the hybrid scenario process (modelers and issue-experts) on the CIB (and thus on the scenario composition a sampling themselves) was very limited (namely close to zero).

7.3.4 Traceability of the modeling and simulation and the resulting outputs (phase 4)

7.3.4.1 Summary traceability assessments[356]

Table 32 gives a very brief overview of the overall traceability assessments concerning modeling, simulation and resulting outputs (2nd half of the numerical scenarios). The traceability of the model building and simulation phases and of the calculated simulation outputs was overall perceived as low

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354 See e. g. FN February 2013 (168-171), This might have been due to the fact that the descriptor essays lose their ‘advocate’ at the end of 2012, because this scenario-expert dropped out of the process due to the end of his contract.

355 The confidentiality of some of the data poses the problem of sharing this data within the project and of officially using this data—that is nevertheless, somehow, used without unveiling its source. (NF February 2013, 186-190: “*Background: There is a mysterious report circulating in the LiWa project […], being the unique source of information on some areas, that some partners, namely the engineers doing modeling have gotten as confidential information and that was shared with some of the other partners only, but not with the NGOSs. This produces a climate of distrust and is not fostering cooperation! Situation now: Consequence is that the information of this report is somehow there but not really usable. People use it, e. g. as a blueprint to contrast other information with it, but nobody is allowed to quote this report e. g. to write down anything out of it into the descriptor essays*.”

356 Results are summarized across actor groups and across sources of evidence.

by non-modelers. Comprehensibility of LiWatool for non-modelers was limited, this held true for scenario group members as well as for CIB scenario experts.[357]

Table 32: Brief summary of scenario traceability of phase 4, simulation, model building and matching level II (Lima Water)

	Comprehen-sibility of LiWatool model and simulation	Did scenario assumptions remain or become explicit and accessible during model building and simulation and in the resulting numerical scenarios (second half)?		Transparency of procedures of scenario composi-tion and sam-pling?
		On future developments (especial-ly with regard to LiWatool outputs)	On interrelations	
Overall assess-ment	LiWatool black box to non-modelers.	Access to and understandability of model output, internal model as-sumptions and simulation decisions very limited for non-modelers (and especially not to the scenario group). Scenario experts have some select-ed access through personal expla-nations by modelers). Assumptions on qualitative context factors in the background.	Interrelations between input assumptions are not considered in this phase. Assumptions on inter-relations within LiWatool – and their change during the pro-cess remain (mostly) inaccessible for non-modelers.	Scenario sample not much of an issue, exception: What policy simu-lations are plausi-ble in what scenario?

The aims of LiWatool were perceived as unclear and its functioning as a black box by many of the non-modeling actors, who I have interviewed. Externals to the modeling had a lot of questions that remained open. Still, their perception seems to vary in function of their disciplinary background, of the degree of facilitation and explications they had access to, and finally in function of their own hands-on experience with LiWatool. Presentations or even live simulations with LiWatool did not seem to be very understandable neither for externals nor for project partners. Furthermore, simulation (I and II) results (and some of the inputs) were finished rather late and were not all and not immediately understandable neither by the CIB scenario experts nor by the scenario group.

With regard to *assumptions on future developments*, the definitions o model *outputs* (and to a lesser degree this also holds true for mode inputs, see phase 3) and of *further internal model assumptions* made during model building, were not easily accessible to non-modelers (and especially not to the scenario group).[358] The same holds true for additional *assumptions made during simulation*.[359] Still, the scenario experts got some (far from comprehensive or systematic) access to model assumptions

357 For instance, scenario-group member N (interview N t3 54: "*Then we saw it at the first training, and we didn't understand a word of it […]I had no clue what that was for."* Scenario-group member N (interview N t3 56): *„We were lost. We were playing with the tool, but not understanding it. That was when we did the pilot project on Lurin, when we finally saw something but the numbers were useless.*"; see also interview with scenario expert L t2 129.

358 Understanding of *simulation results (input and output)* (simulation I and II) was difficult and also for experts and required personal explication by the modelers. Issues were missing definitions and definitions diverging from CIB as well as the use of terms diverging from the local practice in Lima, which lead to misunderstandings.

359 Accessible documentation of some of the *additional simulation decision***s** (e. g. on distribution of available water to different user groups) is in theory possible through control tables' (cf. FN Ifak 20120427), but these were not used for simulation II anymore. This means, (highly difficult and normative) assumptions have been left to the modeler and were somehow normalized, once they had been implemented.

linked to outputs, internal relations and simulation decision through personal explanations by the modelers.[360]

Overall, access to and understandability of model output, modeling assumptions and simulation decisions was very limited for non-modelers. The empirical material does not show any evidence that *interrelations* between input assumptions were taken into account in this phase. *Assumptions on interrelations* within LiWatool—and their changes during the modelling and simulation process, e. g. during loop IV (see methodology of phase 4) did not become visible but remained inaccessible for non-modelers (cf. interview scenario expert M t2 210).The *scenario composition and sampling* was not much of an issue during model building and simulation with a few exceptions, mainly concerning the issue what policies are suitable to be simulated in what scenario. From the modelers' perspective, scenarios and policies were not separated clearly enough in the CIB scenarios (cf. e. g. interview O t3 31). The rough assumptions on policies already described within the raw CIB scenarios as well as the qualitative context assumptions such as on governance structures, were sometimes not considered (forgotten?) when modelers carried out their simulations (cf. e. g. FN Nov_Dec2012: 65 ff.).

7.3.4.2 Interpretation: effects of CIB vs. other elements of the methodology

Evidence suggests that the combination of LiWatool with CIB scenarios had a slight window effect, supporting the otherwise low understanding of LiWatool for non-modelers. Yet his effect was rather selective as no systematic matching on level II, comparing LiWatool and CIB structures, was carried out.[361]

Understanding LiWatool by non-modelers was an important hurdle to the traceability of (the second half of the) numerical scenarios

First of all, the model building and simulation were perceived as inaccessible and not comprehensible to non-modelers (precondition). LiWatool was perceived as a black box, especially with regard to its internal assumptions (on interrelations), despite two facts: First, in theory, LiWatool is no black box model and also was handed over to project partners;[362] second, verbal explications were given by the modeler to explain, e. g., changes in the calculation of outputs. Still, LiWatool trainings for project

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360 *Many more modeling and simulation decisions remained implicit* for externals, if they were not, by chance, shown e. g. during trainings or revealed to scenario experts during meetings and exchange with the modelers. Some pressure for documentation of assumptions of simulation triggered by the combination, but perhaps not as strong as hoped for.

361 See expectation E6, section 4.5.3.

362 In the modeler's view, LiWatool is *no black box model*, you can look inside to follow formulas behind non trivial results-one can see the interrelations and influence their definition. scenario-group member criticize that only the modeler is able to 'manipulate' LiWatool ('superior knowledge', i.e. the knowledge that is limited to and supports the power of a reigning elite), Interview scenario group member expert N t3 65: „*One thing is that LiWa-Tool is difficult to understand and another that the modeler is the only one who can manipulate it clearly*." Even though the model was handed over to project partners, non-modelers do not have the capacities of 'looking into the black box'.

partners and stakeholders that were realized in the project provided a 'hands-on experience', which was perceived as very helpful to increase the LiWatool understanding of the non-modelers of the project.[363] In the following, this is explained by the methodology of modeling and simulation.

Scenario simulation in the hands of a few modelers hindered traceability for non-modelers

Actors beyond modelers were not much included in this phase[364], with the exception of the CIB-scenario experts, who tried to participate and to get some access to the simulations. The model building itself had a rather separate character. This became visible as modelers and scenario group used diverging terms and labels, and supposedly also had diverging system understandings. Furthermore, actors beyond modelers did not have the necessary disciplinary background and capacities to understand the model well. The final scenario assumptions (internal model assumptions and logic leading to model output) were decided by modelers alone, despite some attempts of communication with scenario experts.

(Automatic) LiWatool output partly in unusual units and/or scales

Furthermore, with regard to *data and presentation of LiWatool* and its results, the comprehensibility of—automatic—LiWatool outputs was difficult. This was not only due to the underlying calculations of outputs that remained unclear to non-modelers, but also due to the use by LiWatool of unclear or not shared terms, diverging units and not easily comparable scales.

Second order effects of CIB through CIB based inputs rather than through matching on level II

The LiWatool model has not been systematically compared with the conceptual CIB model. It is unclear, in how far model assumptions and simulation decisions, made by the modelers alone were indirectly and unconsciously guided by the CIB scenarios: There was no arena and no technique for any systematic form of matching on level II. Thus, the LiWatool simulation did not benefit from the expected *direct* traceability gains through CIB. Overall, CIB had only indirect impact onto this phase. This impact occurred mainly through their indirect impact on model *input data sets* steering the simulation, which I consider an indirect but strong impact.

CIB with an indirect 'window effect' on LiWatool for non-modelers

There are hints that for some members of the scenario group, who, during most of the projects runtime, had very limited access to LiWatool and to its simulation, the aims and functionality of LiWatool became clear(er) at the end of the project. This was supported through the simulation of

363 These trainings were carried out rather late in the process, especially for actors beyond the Lima Water company, which was the central client of the model and for whom earlier trainings had been carried out.

364 See interviews with scenario group members N t3 54, 56; I t2 50; G t2 44.

the known (and explicit) CIB scenarios.[365] Thus, it seems that the simulation of the input scenarios, for these actors, sheds some light on the LiWatool model, even without a systematic or deep understanding of the model itself. The sheer combination with the explicit CIB input scenarios led to some traceability gains of the simulation—albeit limited to familiar and thus interpretable simulation logic and outputs, like the water balances.

Actors' initiative important to stimulate activities of matching on level II

In addition, on the social level, this indirect impact of CIB was enforced through the cooperation of modelers with the CIB scenario experts, working together in parallel on the scenario simulation and integration (cf. mainly phase 5). The scenarios experts were asking the modelers to uncover some of the internal model assumptions and calculation logic behind LiWatool outputs. This resulted in some form of 'matching on level II', requiring the modelers to document their assumptions as well as to explain calculations logic, for example with regard to the issue of water consumption per capita.

Despite potentially diverging degrees of commitment among different scenario experts and modelers to stick to or to be guided by the CIB scenarios, a need for closer cooperation and for more reciprocal understanding was repeatedly expressed. For instance, the scenario experts wished to do scenario simulations together with the modelers and the modelers wished for higher LiWatool competences among scenario experts.

7.3.5 Traceability of the integrated scenarios (phase 5)

7.3.5.1 Summary traceability assessments[366]

Table 33 gives a brief overview of the overall traceability assessments with regard to the integration and iteration phase and the resulting integrated scenarios.

Especially at the beginning of the process, CIB scenario building and LiWatool have been perceived as rather separate activities. Their combination was, especially by the scenario group, understood rather late in the process. Different actors suggested that an exemplary overview of the entire combined methodology would have supported their understanding from the beginning on, as well as more explication and facilitation. With regard to the integrated scenarios, especially the LiWatool

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365 Scenario-group member N (interview t3 58): "*I remember, there was software training here at the NGO's office, with Expert P we were trying to understand it, its goal, the tables he was producing. We could not make a connection between the speech of the mathematician doing his graphs and the city. You know, we are city people, we are architects! What is this going to be useful for, what are we going to do with it and what decisions are we are going to take after this information? Not a clue. <u>Then, when you were making the connection with the scenarios, then, I saw that I got it, at the end of the project, after 5 years</u>." (my emphasis).*

Scenario-group member N (interview t3 60, my emphasis): "*I think, not that sure,* but I think that I got it. <u>Because now, with the numbers that he was asking for and the connection with the scenarios. That connection and the results of the graphs were showing the red line: the water demand and the offer, finally we got it</u>**!**'"

366 Results are summarized across actor groups and across sources of evidence.

provided figures were seen as difficult to understand without further explanation and thus hindered the comprehensibility of the overall integrated scenarios.

Table 33: Summary of scenario traceability of phase 5, integration and iteration (Lima Water)

	Did scenario assumptions remain and /or become explicit and accessible during the integration/iteration phase and in the resulting integrated scenarios?		**Transparency of procedures of scenario composition and sampling?**
	On future developments	**On interrelations**	
Overall assessment	Assumptions on future developments assessed as very explicit. Final and last minute changes of numerical assumptions are not documented and justified in textual form in DEs anymore, the brochure takes over documentation function, also through numerical input and output tables across scenarios. Assumptions gain numerical precision—but loose qualitative information on assumptions behind assumptions.	No issue—with the exception of indirect relevance during consistency check of new scenario C with CIB matrix: traceability of assumptions on interrelations is a precondition for this consistency assessment.	Scenario and sample structures are perceived as traceable by internals as for example the scenario group. In the integrated brochure, scenario composition is justified with 'scientific 'CIB and thus presented as theoretically transparent. Still, (further) reasons beyond CIB for (old and new) sampling not documented, thus not fully traceable for externals.

Within the integrated scenarios, *assumptions on future developments* were assessed as very explicit and accessible by all actors. It seems that for some actors (esp. modelers and the scenario group), they were even more explicit than the mere qualitative formulations of the raw CIB scenarios: Several interviewees stressed the benefit of the numerical input- and output-tables for all scenarios in the annex of the integrated brochure.[367] Beforehand, scenario experts and modelers had been ambivalent with regard to the idea of making (numerical) scenario assumptions explicit: On the one hand explicitness was seen as essential for discussion and local validation (e. g. L t3 75). On the other hand, explicitness was perceived as making you vulnerable for critique. Explicitness on numerical assumptions was even expected to threaten the credibility of the LiWa scenarios.[368] But finally, the explicit and local validation of numbers and correction of errors have been perceived as being essential. On the opposite, the scenario group was very clearly and very positive towards the explicitness of the (numerical) scenario assumptions within the integrated scenarios.[369] They allowed and fostered debates as the discussion of the integrated brochure with the scenario group showed, where, e. g., explicit time series were criticized as being too negative (cf. FN March 2013: 218 ff.). Overall, with the integrated scenarios, a more *numerical level of traceab*ility pertaining to assumptions on future developments was reached. Compared with the initial raw CIB scenarios, the inte-

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[367] Both scenario-group members interviewed in t3 assesse the overview on simulations of all scenarios in input and output tables in the brochure as very good and clear, N t3 3, expert I t3, 69-70, the same assessment was made by the scenario expert L t3 75.

[368] See interview scenario expert L t3 37, and the considerations of modeler O documented in my FN February 2013: 439-444.

[369] Expert N (t3 70): "I think they are clear, you can follow them. The point is, they are going to be argued and contested, for sure. It is nice to have this information about the city. It will open a discussion, a debate. And that is good!"

grated scenarios provided much more numerical precision, but perhaps less depth with regard to qualitative, textual explication on assumptions behind assumptions.

During the integration phase, the interrelations between future developments have been no explicit issue, that is they remained covered up in the CIB matrix. Only at the moment of iteration A, the check of the new scenario C with CIB, they are a relevant precondition to check the consistency of the new scenario C with the original CIB matrix.

With regard to the *scenario composition and the selection of scenario sample, t*he integrated scenarios (V1) were criticized and in part rejected by the scenario group, when they first got access to them during a stakeholder workshop.[370] First, specific time series and scenarios were criticized as being too optimistic. Second, at that point in time, ownership with regard to the *entire scenario sample* seemed to be missing.[371] This led to a reappropriation of the sample through the change of scenario C into a more medium one. In consequence, the *resulting* scenario and sample structures of the final integrated scenarios were then, during interviews t3, perceived as traceable, by members of the scenario group for instance.

The new scenario C was consciously inconsistent with CIB, but its structure is documented in the scenario brochure within the (CIB!) scenario table. Thus, this inconsistency with CIB—in contrast to the other scenario families, that are fully consistent with the CIB—was not being made explicit in the integrated brochure. Instead, the procedures *behind* the scenario construction still are presented with the 'aura of scientificity' gained through the composition with CIB. Overall, the entire *procedures* of scenario composition and sampling, including considerable elements beyond CIB, are not described in brochure in detail. This holds true with regard to the impact of scenario experts on the initial sample and with regard to the impact of the scenario group on the final sample. In consequence, the sampling is not entirely traceable for externals.

7.3.5.2 Interpretation: effects of CIB vs. other elements of the methodology

The degree of traceability of the integrated scenarios can be explained by first, second and third order (i.e. inherited) effects of CIB, as well as by the social and cognitive organization of this phase.

CIB with second (and third order) effects supporting traceability

The effects of CIB on the integration phase were mainly *indirect* through the use of CIB generated *data*. This indirect impact was threefold: First through the use of the CIB scenario table to structure the integrated scenarios, second (and even more indirectly) through the use of the storylines and

370 This workshop at the same time was the first time, the scenario-group got access to the numerical scenarios (inputs and outputs).

371 For instance, scenario-group member expert N was asking (interview t3 47): "*[…] Who owns those scenarios? Who is going to say it's nice, that is what we think? Where is the agreement? and of whom? […] at the end I myself was objecting to some things and was saying already" change this and that" for myself.*"

third, of the numerical scenarios. These scenario versions (storylines and numerical scenarios) were affected individually, and to different degrees, by CIB data as well, in form of effects inherited from CIB, see phases 3, 3* & 4. This indirect impact of CIB on the integration was supported by the actors. As a CIB advocate, I decided, for example, to structure the integrated scenario brochure (more or less) following the CIB descriptor structure. My impact then ended at the end of March 2013 and the modelers took over the task of following this structure. I assume that this multiple use of the CIB table supported the transport of scenario assumptions on future developments from the raw CIB scenarios up into the integrated scenarios. Still, this prominent use of the CIB scenario table instead of the CIB matrix might have helped to cover the scenario assumptions again and to bury them in the (rarely used) matrix.

CIB had a direct impact during the iteration phase only, when CIB itself was used by the scenario experts to reveal the inconsistencies of the structure of new scenario C with the CIB matrix (no. 10), and when they built a new test matrix (no. 11) consistent with this scenario. As this step was a dead end within the process, this direct use of CIB had no substantial effect on the (traceability) of the scenario sample, except for uncovering the inconsistency of new scenario C with the assumptions on interrelations stored in the CIB matrix.

Ambivalent traceability effects through the writing of the integrated brochure

It is possible that the writing of the integrated brochure and thus the combination of storylines and numerical scenarios had positive effects on perceived scenario traceability, too. It seems that the additional quantification of the scenarios through the matching on level I (first half of numerical scenarios) and the simulation with LiWatool (second half of the numerical scenarios), which were added to the verbal storyline text within the integrated scenarios, increased the traceability of the scenarios with regard to assumptions on future developments. These additional *numerical* formulations of the scenarios and the comparative presentation of scenarios through the input and output tables seem to have fostered the critical discussion of scenario assumptions *and* of the—until then relatively unquestioned—scenario sample through the scenario group.

Furthermore, within the integrated scenarios, simulation inputs and outputs are again embedded in the qualitative context assumptions, e. g. on governance, which had disappeared during matching and had been sometimes forgotten during policy simulations. Qualitative context assumptions are thus made explicit again.

On the downside, the writing of the integrated brochure left little room for the presentation of interrelations. These were only presented very selectively, to a comparably minor degree, as within the short version of the storylines. The integrated brochure left little room for extensive documentation of assumptions behind short titles, meaning assumptions behind assumptions, as they had been established in the internal descriptor essays. Furthermore, the scenario construction and the sampling are not 100% documented within the final version of scenario brochure, suggesting that the scenario construction procedures and the entire sample are based on a scientific, CIB-supported selection. Instead, in the project reality, the scenario expert's analysis, the perspective of the overall LiWa project, and stakeholders' ownership finally prevailed over a dogmatic 100% application of CIB. Still, this is not openly documented.

Non-inclusion of actors complicates traceability

The role of actors in supporting the effects of CIB was already mentioned above. The fact that actors were no longer present or not included in specific activities had further impacts on the traceability of the integrated scenarios: First the descriptor essays had lost their 'responsible' even before the start of the integration phase at the end of 2012. This had led to the tacit decision to give up this tool for documentation in the heat of the finalization of the integrated scenarios.[372] The modelers, during the very intense final phase of the process, were supplying simulation results that nobody else was immediately able to check or to trace. Finally, the scenario group had been (for many reasons, mainly of practicability) quasi excluded, not only from the matching on level I, from the modeling and simulation, but *also* from the production of the integrated scenario brochure. They were externals to this phase. Thus, when the almost final numerical scenario information (inputs and outputs) were presented to the scenario group, further ex-post cognitive integration was required, which produced much confusion.[373] The scenario group reappropriated their scenarios, after they had been translated into numbers by others, namely by the German researchers. This reappropriation also concerned the scenario composition and sampling. From the beginning of the process on, the scenario group's participation in this activity had been rather symbolic. It seems that the renewed sample was perceived as more acceptable and more traceable. In addition, the modelers' system perception was newly integrated into the final integrated scenarios through the numerical scenarios.

CIB table added by input- output tables across scenarios as a new piece of access

With regard to *data*, the CIB table *and* the overview tables on simulation input and output were the central and visible sources for (overview) information on scenario assumptions and on the scenario sample. The CIB matrix, being the only one providing information on interrelations was banned to

372 FN February 2013, 268-270: "Overall, these ad hoc last minute changes are not yet documented in the descriptor essays yet, i.e. not made transparent for people not involved into the process." The scenario brochure took over the documentation function but, in contrast to the—rather long—descriptor essays, left out most of the reasoning and all of the justifications *behind* these assumptions.

373 E. g. scenario-group member N (interview t3 39): "*First, at one point, I was thinking, it should be a different number. Because I saw the numbers in the brochure but it was another one I knew from the INEI [Peruvian national institute of statistics]. That was one thing. Some numbers I think we did not agree with them, as they were in the table. First, I thought that was a mistake or a misunderstanding and suddenly, there were some other people saying 'Yes, it is like that!'. So we were restarting the discussion of the numbers. Although at least Expert L had thought that we were agreeing on them, but we said 'we are not'. That was the first problem: that was some problem of communication, it was not that clear, on poverty and especially not on the growth rate of the population.*"

the annex of the integrated brochure—the textual justifications of interrelations were almost completely left out.

Conditions hostile to scenario traceability

Overall, the scenario integration was realized under conditions hostile to traceability. Among other things, resources were very scarce; also there was no time for substantial changes, such as a full iteration (by changing the CIB matrix and the entire sample).

Paradox effects on scenario traceability

Overall, during the final phase, there have been paradox effects on scenario traceability. The numerical scenario information was perceived to support the scenario traceability *despite* the multiple sources of non-traceability, which were brought into the scenario process, when this numerical information was generated. Central sources of non-traceability were the closed shop character of model building and simulation; and the lack of explications, justification and documentation behind qualitative *and* numerical formulations (assumptions behind assumptions). Also, the raw CIB scenarios were pushed further into the background and most assumptions on interrelations were covered. At the same time, simulation results were explicitly embedded in their qualitative context assumptions again. These context assumptions had been pushed into the background during matching and at times had been forgotten during simulation.

7.4 Scenario consistency*:* Assessments and interpretation of effects

Scenario consistency was analyzed phase by phase through the methodology. First, for each form of scenarios, the degree of consistency is assessed. Results are presented in the following as consistency assessments. Second, possible reasons within the methodology are provided that explain the degree of consistency of the specific scenario products. I discern between the direct and indirect (propagated) effects of CIB and the effects of other elements of the methodology. These results are summarized as interpretation of effects. For brevity, only summaries of the different consistency analyses are presented. Detail can be found in Annex JJ to Annex PP, and Annex RR to Annex UU.

7.4.1 Consistency of the raw CIB scenarios (phase 2)

In the Lima Water case, CIB and its consistency logic were correctly used to compose and select raw CIB scenarios in the Lima Water case. Thus, following the consistency assumption of CIB, these raw CIB scenarios are *internally* consistent with regard to the (causal) consistency criterion of CIB. As all scenarios of the sample are based on one and the same CIB matrix,[374] there is also *consistency within* the scenario sample, according to the CIB consistency criterion.[375]

7.4.2 Consistency of the storylines (phase 3*)

7.4.2.1 Summary consistency assessment[376]

In sum, the *internal* consistency of the CIB raw scenarios survived the storyline writing process for quite a long time and quite well through different versions of storyline products (up to the narrative parts of the integrated scenarios). The same holds true for the consistency *within* the scenario sample. Table 34 briefly summarizes the apparent consistency with regard to the *structure* and with regard to the *content* of the narrative forms of the scenarios with the raw CIB scenarios. For more detail, see Annex LL.

Table 34: Summary of (apparent) consistency between storylines and raw CIB scenarios; see Annex LL for details (Lima Water)

	Consistency between (comparison with raw CIB scenarios)			
	Structure		Content	
	Indiv. scenarios	Sample	D&V	Interrelations
Over-all	*Apparently consistent with structure of raw CIB scenario configura-tions; Short versions sum-ming up some de-scriptors.*	*Consistent with CIB reference scenario sam-ples over time).*	*Overall apparently consistent with raw CIB scenarios, lacking some precision in definitions; adding some new elements but which are not necessarily con-tradictory; some definitions slightly changed.*	*Mostly not described in storylines (→ not possible to compare mental models of writer vs. matrix).*

Overall, in the Lima Water case, the individual long and short storylines and their samples are apparently consistent with the corresponding raw CIB scenario samples. This applies to the scenario *structure* and basically also to the scenario *content*, except for some cases of lacking precision and additions in the case of the short version—but which are not necessarily contradictory. Assumptions

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374 This scenario sample was based on the same CIB matrix until March 2014. Still, for scenario selection, the climate effects were, so to speak, externally controlled. Therefore, in a *strict sense*, those scenarios assuming *dry* climate change are consistent with one variant of the CIB matrix and with each other and all scenarios assuming *wet* climate change are consistent with another variant of the CIB matrix and with each other.

375 This effect of CIB is *assumed* and *not analyzed* in this study (see section 4.5.3.3).

376 The following consistency assessment is based on a content analysis of the different narrative scenario products, comparing the *apparent* consistency of structure and content of the storylines with the structure and content of the CIB scenarios. The level of *apparent* consistency was chosen as at most instances, more systematic criteria, e. g. as the one of CIB were not applicable. These would require more information on assumptions on interrelations which were not accessible and thus not comparable in this case. This analysis is based on evidence from process documents stored in Supplement C_CIB vs. storylines over time Lima Water. More detailed information on consistency assessments of narrative storylines can be found in Annex JJ (scenario *structure*) and Annex KK (scenario *content).*

on interrelations have mostly not been described in storylines, thus this consistency assessment is on the level of *appearance* only.[377]

7.4.2.2 Interpretation: effects of CIB vs. other elements of the methodology

Overall, the propagation of structures and contents of the raw CIB scenarios into the storylines was supported through the use of CIB-generated data and through the activities of CIB advocates. These second-order effects of CIB counterbalanced the impact of local actors on the storylines. The fact that the actors were striving for local appropriation and ownership threatened the propagation of the CIB scenario structure and content.

Strong second-order effects of CIB through data and actors kept storylines consistent with the raw CIB scenarios

CIB had strong second-order effects on the storylines through CIB-generated data. The process of storyline writing was not supported by any scenario writing method sui generis, but was instead heavily supported and streamlined by CIB generated data, namely the CIB matrix as well as the scenario table, the protocol and the impact diagrams. The support by these CIB products was of considerable help to the scenario experts when they were generating the long storyline texts and trying to keep them consistent with the raw CIB scenarios.

New actors' striving for local anchorage and ownership threatened consistency

During the phase of storyline writing, several actors beyond the core scenario team influenced the process: scenario group members, external stakeholders, and especially the first author of the short versions of the storylines, that is scenario group member P, who had no access to the ScenarioWizard protocols and impact diagrams. The CIB method came into play only a posteriori, during the integration of the comments by external experts (Loop II). Given these conditions, the short versions were even impressively consistent with the raw CIB scenarios. They contained a few additional elements not covered by the raw CIB scenarios. These additions seem to have been the result of the particular perspective of the Peruvian author. He had intended to give the storylines "more [local] detail and color" (FN March 2012: 141). The long versions were perceived as being rather neutral, dry and not well anchored in the local realities, which had been mainly produced by German researchers. [378]

In sum, there was an apparent *tension* between neutrality, systematic structure and consistency with the CIB scenarios on the one hand, and the local appropriation and ownership of the storylines on

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[377] In this study, it was not possible to compare e. g. the mental models of writers with the matrix.

[378] See e. g. scenario-expert M (interview t2 38): *"No matter who writes it here, there will always be a focus on one of the descriptors or perhaps not on a descriptor, but on my area of expertise. Which again biases the whole thing. Maybe it would have been easier to read, but I could imagine that it would also have been more one-sided. So therefore I think it is not bad to get a framework from the outside, but I think it is not possible either for the framework from the outside to be accepted by the group and to continue to be used without criticism."*

the other hand. The propagation of consistency in terms of CIB therefore was not realized automatically, but had to be supported actively by the scenario experts. These carried out repeated consistency controls of the storyline texts using the CIB data as input and the CIB matrix as the final benchmark. Here, I certainly played a role in the position of a CIB advocate. Every time the storylines left the scenario experts' inner circle and were worked on by other actors—the student assistants for translation, the scenario group members, the external stakeholders—the more freedom they gained and the more inconsistencies occurred with the CIB scenarios. These threats to consistency were then controlled by the scenario experts. The minor inconsistencies during the draft of the short versions and introduced through feedback during RTII were repaired through comparisons with and adaptations of the CIB matrix (see loop II, e. g.).

7.4.3 Consistency of the numerical input data sets (phase 3)

7.4.3.1 Summary consistency assessment[379]

In sum, the numerical input data sets are fairly consistent with the raw CIB scenarios, when it comes to scenario structure and content. Exceptions were untranslated and partially translated descriptors; one rather inconsistent indicator; time series with little spread; and finally, the input data set corresponding to scenario C, which had no equivalent in the CIB scenarios. Over time, *apparent* consistency with the raw CIB scenarios increased.[380] This held true with the exception of changes to the structure of the final scenario C. This overall result is explained in more detail in the following section. For a very brief overview, see Table 35; for more detail on results, see Annex PP.[381]

The *individual structures* of the individual input data sets are fairly consistent with the structures of the translatable part of the corresponding raw CIB scenarios (see also Annex MM). The two earlier versions, resulting from the matching process (*before* integration) contain three inconsistent moments that were corrected in the later versions, *after* integration.[382] Overall, the individual input data

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379 The following consistency assessments are based on a content analysis of the different versions of the numerical input data sets, comparing the *apparent* consistency of structure and content of the numerical input data sets with the content and structure of the raw CIB scenarios. This analysis is based on process documents stored in Supplement D_CIB vs. input data over time Lima Water. Detailed information on the consistency assessment can be found in Annex MM (comparison of scenario and sample structures of sets vs. CIB scenarios), Annex NN (scenario content: comparison of CIB descriptors vs. numerical indicators) and Annex OO (scenario content: comparison of CIB variants vs. time series).

380 Still, they are consistent on the level of appearance, i.e. on the surface of the resulting scenarios only: The input data sets appear as (certainly somewhat biased) numerical 'transfer pictures', but do not go into the systematic consideration and depth of interrelations themselves, and thus only indirectly transport the internal consistency of the raw CIB scenarios.

381 Annex PP sums up results from the analysis of four central versions of numerical input data sets (from the set used for the first simulation to the set underlying the final version of the integrated brochure).

382 Issues of inconsistencies in the sample structure that occurred over time, and which were due to the ambiguities contained in the sets of reference scenarios (e. g. due to variants with regard to assumption on climate change), have been corrected. Inconsistencies in scenario structure that occurred due to redefini-

sets became more consistent with the CIB scenario structure over time. The numerical-input data-set *samples* correspond to the CIB configurations documented in the reference tables. This holds true with the exception of the structure of scenario C which, in the final version of input data sets after iteration, corresponds to the structure of the new scenario C.

Table 35: Summary of (apparent) consistency between input data sets and raw CIB scenarios; see Annex PP for details with regard to different versions (Lima Water)

	Consistency between (comparison with raw CIB scenarios)			
	Structure		**Structure**	
	Indiv. scenarios	**Sample**	**D&V**	**Interrelations**
Overall	Individual input data sets become more consistent with CIB scenario structure over time.	Input data set samples correspond to CIB reference tables.	**indicators**: All input data sets: • 10 out of 13 descriptors somehow quantified in the form of input data. o 5 out of 10 descriptors represented by more than one indicator. o 5 out of 10 indicators only partial representations of descriptors, one indicator is larger than the descriptor (NSE). o Further specification (and split) of indicators over time. • Overall, translated (parts of)descriptors consistent, except for NSE for poverty. **Time series:** • Overall, TS became more specific and more split over time. • Overall, TS are consistent in direction (all) and spread with variants. • Several TS become more conservative in spread over time, as for example C (tariffs), E (poverty) or J (coverage rate), some TS become larger in spread over time, e. g. M (climate change).	Assumptions on interrelation not visible in time series—not made explicit in a systematic way—no comparison with CIB possible.

With respect to content and indicators, see Annex NN, the quantifiable part of the raw CIB scenarios was quite considerable with 10 out of 13 descriptors. Five out of 10 descriptors were represented by more than one indicator, namely through the split of information contained in the qualitative descriptors into more than one indicator. Out of the ten descriptors, four were translated fully and consistently by (one or more) numerical indicators covering the entire descriptor's content-wise scope. For five further descriptors, indicators were found that only partially covered the ideas verbally expressed by the descriptors. But the part they did cover, they covered in a way that was in line with the ideas expressed by the corresponding CIB descriptors. Only one out of the ten indicators was not fully consistent (indicator NSE for the descriptor 'poverty'), as it was larger than the concept defined by the qualitative descriptor. Over time, further specification (and split) of indicators occurred. In

tions and new interpretations of descriptors through very partial indicators were adjusted and were, in the end, oriented toward the general scenario family logic and not toward the variant structure of the raw CIB scenarios.

sum, the numerical indicators found for—the translated part of—the CIB descriptors were reasonably adequate numerical representatives of the descriptors.

Overall, the developed time series (TS) were consistent with the direction of the developments described in the individual descriptor variants and rather consistent with the spread between the variants of one description, see Annex OO. Over time, some TS became more specific and were further split up (indicators); some became more conservative in their spread, as for example C (tariffs), E (poverty) or J (coverage), a few became larger in spread over time, e. g. M (climate change).[383]

Interrelations between input parameters were not taken into account systematically during matching and thus no systematic comparison with the CIB is possible. Issues of interrelations were raised during the definition of some of the time series only. As described above, for developing time series for the descriptors tariffs and green area, assumptions on interrelations were uncovered and compared with the CIB assumptions, see the methodology of matching and loop III.[384] The numerical input data sets did, at least implicitly, suggest assumptions on interrelations—albeit to a lesser degree than the CIB—and are not bundles of isolated input data.

7.4.3.2 Interpretation: effects of CIB vs. other elements of the methodology

Overall, the individual structures of the early individual input data sets (TS1 and TS2) are more or less consistent with the structure of the translatable part of the corresponding raw CIB scenarios. The numerical input data set samples fully correspond to the sets of CIB configurations documented in the reference tables. The scenario content of the internally consistent raw CIB scenarios survived the process of matching rather well. The numerical indicators found for the translated part of the CIB descriptors became, over time, more or less adequate numerical representatives of the descriptors. Versions TS 3 an TS 4 can be assessed as most adequate. Alltogether, the effects on scenario consistency of the different elements of the methodology of matching are multiple and complex, in the sense that on each level many different promoting and hindering influences came together. CIB had mainly second-order effects supporting the scenario consistency of the numerical input data sets through data and actors, as explained in the following section.

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383 The reasons for these changes of spread were multiple (e. g. new base year, new data, and adaptations in function of simulation results). The direction may have been more clearly indicated by the qualitative definition than by the spread, which left more freedom to the input data definition (see the interpretation below).

384 In the case of tariffs, there was an initial mismatch between the scenario group's assumptions on the *direction* of the impact logic ("cost-effective tariffs foster more infrastructure") and those of the issue expert ("the planning of more infrastructure projects is the precondition for increasing tariffs"). In the end this was only a minor issue of consistency since, in the scenarios, both ideas, independent of their direction, resulted in either cost effective tariffs *and* more infrastructure or no cost-effective tariffs *and* no increase in infrastructure. Thus, the direction of their causal relation was contested but both developments remained consistent on the level of *coincidence* (cf. FN January 2012 and FN WS tariffs II 20120606).

Other methods with ambivalent or hindering effects

The automatic import of the CIB based input data sets into LiWatool through a small software code (instead of manual selection of different individual input values) supported the consistency of the scenario structure of input data sets. But the necessity of selecting each set per simulation by hand through copy and paste, was still a source of error, as the confusion concerning time series on poverty shows. Furthermore, the adaptation of indicators and time series in response to LiWatool needs (e. g. NSE) and in function of simulation results (see Loop IV, e. g.) was hindering consistency.

Challenging cooperation of actors—with multiple effects

During matching, scenarios experts including myself sometimes acted as advocates of the CIB scenarios (with regard to structure and content) by conducting consistency checks for individual time series and for sets of input data. In addition, close consultation between modelers and scenario experts during the matching, and the actors' willingness to cooperate, and their readiness to invest a lot of time to compensate for difficulties (for example the lack of resources) certainly worked to foster consistency in the input data sets with the raw CIB scenarios. Furthermore, modelers and issue experts understood the system differently from the scenario group. The former had a more academic view, based on their own research; the latter had a more subjective and political view. Still, modelers and issue experts sought to understand and to reproduce the scenario group's ideas, sometimes by consulting the matrix (ex-post cognitive integration and the need for reappropriation). Individual stakeholders, who had been consulted in their role as local issue experts during matching, clearly had political preferences with regard to the definition of the status quo and of desirable possible numerical future developments. In consequence, they had an impact on the definition of time series that was not necessarily consistent with the ideas of the raw CIB scenarios—and consequently with those of the scenario group as a whole.

Different forms of data with opposite effects on consistency of numerical input data sets

The use of the CIB reference scenario table by the modelers clearly strengthened consistency.[385] In addition, the descriptor essays played an important role, providing additional information on the scenario groups' assumptions. During matching, the CIB matrix was used at select moments only (cf. loop II, e. g.). Also, modelers perceived important degrees of freedom mainly with regard to the type of indicators (for instance, to split them into more than one, or to choose indicators providing a partial translation only) and with regard to the spread of selected time series—but less with regard to the direction of developments.

[385] At least once the ambivalence within the reference table was taken away through the reduction to seven reference configurations.

At the same time, numerical information brought in by local experts (especially by the water company, but also by NGOs) was often strongly normatively loaded. Especially the definition of the status quo involved politically sensible issues, see the issue of combat numbers and performance indicators described above. In addition, choosing readily available data (e. g. with regard to NSE), also meant choosing indicators and/ or time series that were not fully consistent with the initial qualitative definition implemented in the CIB.

The timing, the separate character and the duration of matching hindered scenario consistency

The matching was realized mainly after and separately from the completion of the CIB analysis. Thus, during matching, the LiWa scenarios were no longer very open to integrating the modelers' and issue experts' perspectives. Instead, these actors had to reappropriate the readymade raw CIB scenarios to interpret, what the scenario group might have meant with their qualitative definitions, and to translate this in numerical terms (see the issue of 'indirect cognitive integration between the system perspective of modelers and scenario groups above). It may be due to the duration of the process and the repeatedly updated status quo data that the gap between the initial perceptions of the system that were stored in the CIB matrix and the actors' perceptions of the system during matching fell apart.

In sum, the actors, who finally decided about numerical input data (i.e. the modelers), were not the ones, who had constructed the CIB scenarios (i.e. mainly the scenario group). Hence, they took their decisions from a different perspective *and* at different moments.

7.4.4 Consistency of model output (and of underlying models) (phase 4)

In the Lima Water case, the conceptual CIB and the numerical LiWatool model had a specific area of overlap: Water consumption per capita per day is a descriptor of CIB; it was also calculated by LiWatool as a simulation output. This raised issues of consistency that are briefly discussed in the following section.

7.4.4.1 Summary consistency assessment

Overall, evidence suggests that water consumption per capita per day is not defined completely identically by CIB and LiWatool. Nevertheless, assumptions on future developments calculated by LiWatool are apparently consistent with the qualitative assumptions by the corresponding CIB scenarios, see Annex QQ.

In the raw CIB scenarios, the descriptor F domestic water consumption per capita per day is *assumed* to be decreasing across all four scenarios. This corresponds to the LiWatool output (versions integration and iteration), *calculating* decreasing (domestic and industrial) water consumption across all scenarios, with the identical and highest values for scenarios A and B1, and the lowest value for scenario B2. The *direction* of the calculations by LiWatool (both versions) is thus apparently consistent with the CIB assumptions.

7.4.4.2 Interpretation of effects

This apparent consistency cannot be explained by any systematic or explicit matching on the level of underlying models (level II)—as none of this occurred in such form.

The apparent consistency might also be a random product. A comparison of underlying influencing factors and their assumed interrelations in both models would be required, in order to fully comprehend two aspects: First, why is decreasing water consumption per capita assumed by the CIB across the different scenarios and also calculated by LiWatool; and second, how does LiWatool arrive at the individually different levels of water in different scenarios? It goes beyond the scope of this study to provide this comparison ex post, an explanation that was not explicitly and systematically given during the project itself. Based on the empirical material and my limited access to LiWatool model versions over time, I can neither investigate changes in the internal model structures nor link those to the rare moments of 'matching on the level of underlying models', which I have identified. Nevertheless, I suppose that some sort of indirect consistency effects between the CIB model and the LiWatool model occurred, through the close cooperation between modelers and scenario experts. These effects might have led to implicit and non-systematic forms of matching on level II. This means the LiWatool model assumption (behind inputs as well as outputs) might have been adapted with respect to the CIB, at least on the level of scenarios, during processes to which I may not have had access to.

7.4.5 Consistency of the integrated scenarios (phase 5)[386]

7.4.5.1 Summary consistency assessment

This consistency assessment is split into two aspects, comparing the apparent consistency between raw CIB scenarios and integrated scenarios (I) and between narrative and numerical parts of the integrated scenarios (II).

With regard to the first aspect (I): *Are the integrated scenarios apparently consistent with the raw CIB scenarios?* In sum, on the level of appearance and with the exception of the final scenario C, the in-

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[386] Note that purely qualitative descriptions are considered narrative parts of the integrated scenario brochure. Descriptions of numerical model assumptions or (output), i.e. text containing numbers, are considered numerical parts. These numerical text passages are indicated in the brochure with a blue background. This analysis took into account *input-related* numerical information, and only on the level of *apparent* consistency.

tegrated scenarios are quite consistent with the raw CIB scenarios. For a brief overview, see Table 36 and for more details of the analysis Annex JJ - Annex OO and Annex SS for a summary of results.[387]

Table 36: Summary of (apparent) consistency between integrated scenarios (narrative and numerical parts V1 and V2) and CIB), see Annex SS for more details (Lima Water)

	Apparent consistency between (Comparison with raw CIB scenarios)			
	Structure		**Content**	
	Indiv. scenarios structure	**Sample structure**	**D&V**	**Interrelations**
Overall	Consistent. Except for scenario structure of narrative text and of input data representing scenario C in V2.	Narrative and numerical parts consistent with CIB reference scenario sample (except for scenario C in V2).	Narrative parts quite consistent with raw CIB scenarios. Numerical parts are a partial translation, translated parts are rather consistent: - As to choice of (in part partial) indicators (except for poverty). - As to direction of time series. Spread of time series became smallest in T2, except for issue M (climate change). Overall, the numerical parts are more or less consistent.	Integrated scenarios rather silent on interrelations, comparison with assumptions of CIB only possible for a few narrative descriptions.

The *structures of individual integrated scenarios* are consistent with the corresponding CIB configurations, except for the structure of narrative text and of input data representing scenario C in V2 (not based on any internally consistent CIB configuration). The order of presentation of issues follows thematic blocks that correspond to the CIB descriptors, albeit clustered differently, namely by content, into four groups.[388] With regard to the sample structure, narrative parts and input data parts of integrated scenarios are consistent with CIB reference scenario sample (except for scenario C in V2).

With regard to scenario content, compared with the descriptors and variants of the raw CIB scenarios, the narrative parts of integrated scenarios are quite consistent with the raw CIB scenarios (for their development over time and a comparison with the initial storylines, see also Annex LL.

The numerical parts (mainly the input data, see also the consistency assessment of these) are a partial translation only. Nevertheless, the translated parts are more consistent than prior versions of input data. They are fairly consistent regarding the choice of indicators (except for the indicator representing poverty) and regarding the direction of time series. The spread of time series became considerably smaller over time and again smaller in V2, except as regards issue M (climate change).[389] Concer-ning *interrelations*, integrated scenarios remain rather silent, a comparison with assumptions of CIB are possible for a few narrative descriptions only.

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387 See Supplement C_CIB vs. storylines over time Lima Water.

388 These differ slightly from the clustering chosen for the storylines and are not arranged in identical order for every scenario.

389 For the development of numerical input data over time and a comparison with the earlier versions of input data sets before integration, see Annex PP.

With regard to the second aspect (II): *Are the narrative and numerical parts of the integrated scenarios consistent with each other?*[390] On the level of appearance, the narrative and numerical parts of *all* scenario families are quite consistent with each other. For a brief overall summary, see Table 37, for more detail of the analysis, see Annex RR and Annex TT, and for a summary of results, see Annex UU.

Table 37: Summary of (apparent) consistency between narrative and numerical parts of integrated scenarios; see Annex UU for more details also with regard to different versions (Lima Water)

	Apparent consistency between narrative and numerical parts			
	Structure		**Content**	
	Indi. scenarios' structure	**sample structure**	**descriptors and variants**	**interrelations**
Overall	Individual scenario structure and sample structure fully consistent with each other in narrative and numerical parts of all integrated scenarios, both versions of brochures.		Highly consistent	Only a few stated in narrative parts only. No comparison possible.

Individual scenarios' structures and sample structure of narrative parts and input data related parts of all integrated scenarios are fully consistent with each other in both versions of brochures (apparent consistency).

With regard to *content*, apparent consistency between narrative parts and input data related parts is high. For some issues, the information given by the integrated brochure is highly integrated as for example with regard to demography, where both types of information are merged within one sentence. For other issues, even only numerical information without any qualification (e. g. descriptors E and J), for others only qualitative text is given. For the latter cases, numerical information is provided in the annex tables of the integrated brochure only (for descriptor F, e. g.).[391]

7.4.5.2 Interpretation: Effects of CIB vs. other elements of the methodology

Tracing the rather high consistency level of the integrated scenarios back to effects of the methodology of integration and iteration shows that the elements of the methodology of these phases had both promoting and hindering effects with regard to consistency. Main effects of the different elements are presented in the following. Overall, it seems that in the Lima water case, integration *supported* scenario consistency. Iteration—albeit no full iteration in the sense of SAS— *hindered* full consistency according to CIB, yet increased consistency of the scenario sample with the scenario group's system perceptions. [392]

390 With this question, I am leaving the issue of consistency with CIB. Instead, narrative and numerical parts of the integrated scenarios are considered mutual consistency benchmarks.

391 In V2, after iteration, one inconsistency was found: In the new scenario C (with regard to demography), the narrative text the old one, assuming high population growth, the numerical value was adapted to the new more medium assumption.

392 Note that this is an interpretation based on the evidence and reflection of this single case and no proof. I consider effects of the methodology on *consistency between* (on the three levels): Numerical input sets

The inherited (in-)consistency effects of CIB and of other factors

Based on the analysis of effects of CIB on storylines and input data sets (before integration), I consider that both narrative and numerical (input data related) parts of the integrated scenarios are based on products that have been both individually derived from the raw CIB scenarios. Thus, they have inherited the respective consistency degrees from the individual storyline writing and matching processes (phases 3* and 3). These were mainly caused by second order effects of CIB (mainly through data and actors, cf. above) and by effects of other elements. I assume that biases and inconsistencies of both versions have propagated to the integrated scenarios, too.

CIB products were (pre-)structuring the integrated scenarios

During the integration phase itself, CIB had second order effects through the use of the CIB scenario table to (pre-)structure the integrated scenarios. These were further structured through four thematic blocks per scenario that each organized and included narrative and numerical (input) elements corresponding to CIB descriptors and additional output information. For instance, the narrative parts became more consistent with the CIB raw scenarios than the prior short versions, e. g. by covering all descriptors. In addition, verbal descriptor and variant definitions were taken up into the text again, which had been left out of the short versions. With regard to the numerical parts, the time series underlying the first version of the integrated brochure certainly have been influenced by the consistency checks against the raw CIB scenarios and the descriptor essays.

Inherited and pre-structuring effects on the level of apparent consistency only

Both effects play on the consistency of the integrated scenarios with CIB on the level of appearance only (narrative and numerical 'transfer pictures'). Assumptions on interrelations are mostly not considered, not represented (or even ignored)—but the scenarios (configurations)are implicitly based on these.

Use of CIB to assert and inform about inconsistency

Furthermore, during integration activities, I have used the CIB matrix for consistency checks of numerical input data sets, and informed scenario experts and modelers about inconsistencies (cf. FN December 2012, FN January 2013). Finally, during iteration A, the CIB method was used to check the consistency of the newly proposed scenario C and to test the new potential matrix no. 11. During 'iteration B', the new scenario C was consciously chosen as a scenario being inconsistent in its structure with the internally consistent network constellations of the initial CIB matrix no. 10. Overall, the impact of CIB on the consistency of the integrated scenarios was indirect through data (CIB products

vs. raw CIB scenarios; narrative parts vs. raw CIB scenarios and narrative and numerical parts of the integrated scenarios.

and derived interim products) and actors (HK)—or direct but on the level of information about (in)consistency only.

Through the integrated brochure, numerical and narrative parts became reciprocal benchmarks—at the expense of the raw CIB scenarios

During the preparation and redaction of the integrated brochure, close comparisons of narrative and numerical parts occurred to fully integrate textual and numerical presentations. The integrated scenario writing forced to carry out constant mutual *textual* consistency checks between both parts, "*for not making it too inconsistent*", as one modeler turned it (interview O t3 94).

Doing so supported—at the same time—the integration as well as the apparent (!) consistency between both parts. This consistency is (mostly) maintained also when the structure of scenario C is changed. This change is taken up by the narrative *and* numerical parts of the final version of scenarios.[393] With regard to the numerical parts, there was an orientation of the LiWatool simulations at the qualitative scenario ideas (overall ideas). This orientation of the simulations happened to 'bring the problem back in'; that means to obtain calculations of water deficits per scenario, which intuitively match the corresponding storylines, for example. With regard to narrative parts, there are hints that the production of the integrated brochure did foster a more systematic and comprehensive description of the narrative parts also through the additional numerical information on the phenomena. Numerical indicators and time series, e. g. representing network losses, fostered precision and detail. For some other issues, the integrated brochure does not contain purely textual qualifications anymore, but the narrative CIB based definition is entirely replaced by the numerical model assumption (e. g. with regard to poverty that is replaced by assumptions on the development of the indicator NSE).

In total, in this phase, the narrative and numerical parts come closer together, but gain more distance from the CIB 'transfer-model'.

Actors with different degrees of awareness and attention to consistency

In the integration phase, actors exhibited varying degrees of awareness and attention to consistency with CIB, and different ideas concerning the strictness of its application, e. g. during the matching process:[394] The *modelers* were less concerned with consistency with CIB than were the scenario ex-

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393 With the exception of the verbal formulation of the demographic development that remained unchanged—which might be explained by a slip of pen that occurred in the heat of finalizing the brochure—and which is not contradicting the numerical assumption either.

394 Overall, evidence suggests that for none of the four interviewed modelers was consistency a classical issue they needed to be concerned with in their normal work (cf. e. g. interviews intern modelers Q t2 180 ff. and O t2 269- 272; as well as external modelers 4 t2 137 ff. and 5 t2 89 ff.). Further questions that arouse during integration were as follows.

1) *Who cares about the consistency between CIB and numerical input?*

perts. For the scenario group, internal consistency was clearly also less important than the construction of meaningful scenarios linked to their current reality, as well as a perception of the system as expressed by the final scenario C**.**

Actors for whom CIB is not a priority have the final say

Scenario experts, including me as a CIB advocate, worked with the modelers towards a joint scenario product. Other scenario experts were more occupied with other pressing project activities such as the development of an action plan. I dropped out of the process in March 2013. The remaining modelers and CIB scenario experts decided to take over the new scenario C, as demanded by the scenario groups, and to leave the CIB logic.

CIB scenarios not consistent with new system perception

It seems that the CIB matrix no. 10 (completed at the end of 2011) and the resulting raw CIB scenario sample were not (intuitively) consistent anymore with the system perceptions of stakeholders at the moment of the integrated scenarios (spring 2013). A *change in* the system may have occurred and, perhaps more important, a change in the stakeholders' understanding and perception of the system and thus of their mental models of the system. An inconsistency between the scenario group's current perceptions of trends and adequate numerical translations of descriptor variants might help to explain the scenario group's disinclination to identify with the numerical forms of scenarios. This

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Clearly there were different *degrees of attention* to the issue of consistency with the qualitative CIB scenarios during the matching process. For instance, during the final interview, the scenario-group member expert I (interview t3) did not seem to perceive any inconsistency between the CIB scenarios and the numerical versions. Also, the modeler expert O did not remember any concrete examples of inconsistencies at the time of the third interview, O t3 92: *"Could you give me another example of inconsistency? I don't have it to hand anymore…"*

2) How strictly do we need to apply it? The degree of 'acceptable inconsistency' might not be the same for all participants, either.

There may have been diverging perceptions of the necessary degree of consistency between CIB scenarios and input parameter sets that is necessary. The modelers were conscious about the need of being consistent to remain credible, but might have been less strict with regard to the necessary degree of consistency than I was. Modeler O (interview t3 94): *"We have to be careful that it does not become too inconsistent, but somehow fits together between text and simulation. Otherwise we would indeed lose confidence."*

3) What is the benchmark?

At times there was no consensus among actors on the benchmark, e. g. when by the modelers, the pre-existing time series are used for orientation, not the qualitative scenario information Interview modeler O (t3 94, my emphasis): "*Finally, the extra defined time series play a role. For my part of the work, the other thing is not irrelevant but certainly not directly relevant. I simply have to know what the numerical time series looks like. That is the most important thing for me. <u>The prose around it is not so important</u> for me. Due to the nature of the matter, I must put something into the quantitative model and simulate."*

See also FN January 2012: 269 ff.: "Modeler O: "For us, numbers are more important…" issue expert: "more important than justifications." [general laughter]."

The time series are perceived as benchmarks for the storylines (not the CIB scenarios). Modeler O (interview t3 94): „*Sometimes things in the prose text are embellished that do not really fit the time series or are not in the time series at all. I no longer know exactly where ... e. g. El Ninos ... How that came in, how that had been interpreted in the time series, I don't know ...*"

went as far as to the rejection of numbers that had earlier been proposed by scenario group members themselves.

> *In any case, there was a change in the perception of possible extreme/ pessimistic descriptor characteristics when we take on board yesterday's discussion, we can see it is now accepted that the population is no longer increasing as sharply. In the case of poverty, the same trend was apparent. I think since Fujimori resigned, this economic policy has been pursued by all three new governments, i.e. foreign investments, social programs, etc. Perhaps people should be told that this time might soon be over too. Only because this has been the trend for the last ten years, does not mean that it will go on for the next 30 years. It depends on who will be leading the city in the future. [...] We would have to bring people out of the perspective, thinking towards prognosis and seeing everything optimistically. Because we think that a lot can happen by 2040. This is perhaps not desirable, but possible. If this happens, we would have taken a big step. But there are also people who say that poverty has been declining for the last 20 years, this trend can no longer be turned.* (CIB scenario expert L t3 45)

This new perception of the system and the tendency toward trend projections might not only explain the choice of new scenario C, but also the fact that the *spread of time series became smallest in V2*, except for issue M (climate change). That means that actors opted for less dramatic assumptions on possible future developments, than they had until 2011. These assumptions fitted better with the stakeholders' then-current perception of possible—and desired—futures for Lima.[395]

Overall, the scenario group's wish to see their less extreme scenario prevailed against any form of so to speak methodological dictatorship, as well as against a full iteration, meaning a loop back to the matrix to adjust it to the apparent new perceptions of the system.

Invested effort supported consistency —scarce resources hindered consistency

Conditions fostering the consistency of the integrated scenarios were that the project invested a considerable amount of time and effort in jointly producing the integrated scenarios. Still, the resources were scarce, simulation results were ready so late that they were just crammed into the scenarios and were merely discussed, understood or checked by actors other than the modelers. For example, during iteration, the decision was made not to adapt and rework the matrix together with the scenario group, that is not to build a new matrix and an entirely renewed scenario sample that might better fit the new ideas of stakeholders and scenario group members. This decision was taken due to the resources required by such a change, which were perceived as far too burdensome and not affordable just before the end of the project.

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[395] Potential alternative explanations for this phenomenon are, first, that the numerical formulations were underdetermined through the CIB, which gave interpretive freedom to the simulation: Hundreds of numerical input data sets might correspond to one and the same qualitative scenario (cf. Trutnevyte/ Stauffacher/ Scholz 2011). Second, it is possible that the phenomenon of conservatism of numbers is being played out here.

7.5 Other (unintended) effects

Evidence suggests two other effects of CIB on the integrated scenario process in the LiWa case.

7.5.1 Disempowering of the modelers and of the scenario group

Through the use of CIB, which requires that the scenario experts have considerable expertise in the method, both modelers and scenario group members lost some power, when it comes to the composition and sampling of scenarios. During the CIB scenario workshops, the members of the scenario group did not discuss comprehensive pictures of the water system of their city. Instead, through the use of the CIB method, they focused their discussion on a short list of system elements with a selected variety of two to three different future developments each and on pairwise influences between possible future developments of these system elements. The discussion was thus brought down to analytical segments of possible futures, as the discussion of effects of the variant of a private water company on other elements of the system, e. g. The *synthetic* task—in contrast to the scenario group's *analytic*al one, of constructing scenarios and selecting a sample—was then left to the CIB scenario experts. Neither the scenario group members nor the modelers were (sufficiently) integrated during this step. This resulted in somewhat limited ownership and, in consequence, to processes of reappropriation.

The scenario group did not have the power to directly influence the pictures generated by the scenarios. The matrix might have reflected their group mental model at a certain point, but certainly also produced counterintuitive results (cf. the episode around the effects of a private company on network losses). It also revealed an important black-or-white logic in the group model, as well as a crucial role ascribed to the governance structures. This deep logic of the CIB matrix led to the rather black-and-white scenarios. Still, the world views underlying this system representation were not further revised by the scenario group as to their appropriateness. Overall, an active conversation with the CIB matrix in the function of a mirror of the group's assumptions did not occur. As a result, the scenario group did not fully identify with the sample as being their own scenarios. At the very end of the process, the scenario group reclaimed their scenario sample by changing scenario C to a less extreme one. This can be read as an act of reappropriation of the scenario sample and at the same time of emancipation from the CIB based sample—and of the scenario experts' control of the sample.

The modelers, normally used to select input data sets for their simulations themselves and used to do so (at least at times) in function of model results, did in this methodological setting give up this impact on the scenarios. In consequence, they lost a part of the influence they had on the output part of the numerical scenarios, too. On the one hand, they seemed willing and somehow relieved to do so. For instance, they perceived the external expertise on societal model contexts as helpful. On the other hand, accepting these scenarios as model input, was very restricting to them, too. This approach created a lot of additional effort in order to define and to document indicators corresponding to CIB descriptors, as well as input time series corresponding to CIB variants. Furthermore, modelling requirements got into tension with qualitative scenario formulations, when e. g. policy simulations were asked to respect scenario constraints albeit *scenario* and *policy* were, from the modelers' view, not separated clearly enough.

It is the case, however, that scenario experts, and especially those with deep experience with CIB, gained a powerful position within the scenario process. Whether and how this distribution of power might provide adequate 'checks and balances'[396] in an integrated scenario process, and whether and under what conditions CIB becomes a steersman or a straightjacket needs to be discussed, see chapter 8.

7.5.2 Closure of the scenario construction and sampling

At least at two instances, the CIB matrix was resistant or inert to adaptations, although good arguments to adapt it had been brought up. First, comments collected from external stakeholders during RT II were checked against the matrix and, in response, the matrix was adapted on the level of textual descriptions of impact assessments only. Second, the discussion of the combined scenario brochure created the new scenario C. Still, it was decided not to adapt the CIB matrix which in response (very probably) would have changed the entire scenario sample.

That means, both times the participants refrained from performing an adaptation of the matrix; both times the argument was made that this would require too much effort and too many resources. The excessive effort was anticipated particularly because of the interrelated nature of the CIB matrix itself: Changing the formulation of a variant requires checking all assumed impacts—not only from this variant on the system, but also from the system on this variant (and potentially to check them in relation to the other options for the variant, as well). Changing *one* impact assessment might require reconsidering *other* impact assessments to adequately work out the relative strength of impacts. And finally, changing the matrix very probably means changing the selection of internally consistent configurations, and thus changing the scenario sample that is justifiable by this CIB matrix. This issue points to the dilemma of openness vs. closure: If a scenario process is open to changes for too long, it will never be finished. On the other hand, if a scenario process is closed too early, and for methodological reasons, it might be perceived as inflexible and method dominated, and might suffer from a lack of ownership, since new or changing perspectives cannot be integrated during the process. I

[396] I.e. reciprocal power control and division of power, originally referring to the political system of the USA.

assume that during CIB processes, once a matrix was filled, these processes might have a tendency to stabilize scenario samples.

7.6 Synthesis: Findings from the case study Lima Water

In this section I sum up the findings from this case by answering the three research questions specific to the Lima Water case (see 5.3.4). First, I briefly sum up the form and function in which CIB was used in the Lima Water case (7.6.1). Second, I summarize first- and second-order effects of CIB (7.6.2). Third, I discuss the degree to which these effects were influenced by further methodological factors and especially by the form of combination with LiWatool (7.6.3). Finally, I briefly summarize central insights from this case (7.6.4).

7.6.1 Form and function of CIB

With regard to the form of combination in the pioneer application of the Lima Water case, CIB was implemented as the steersman of the combined scenario process. CIB was used to define all forms of scenarios regarding content and structure. The numerical modeling contributed to the numerical scenarios, first through the definition of input data sets representing the raw CIB scenarios and second through the calculation of model output. The CIB was used to synthesize central institutional, social, environmental and technological factors affecting the water future of Lima. The LiWatool model was used to specifically analyze the embedded technical water system in a numerical way (system representation). The CIB was completed before the modeling and simulation, and both led and structured the scenario construction process (position). The main link between the components was output-input coupling from CIB to LiWatool. This link was realized mainly on the level of scenarios and not on the level of underlying models, as no systematic or explicit form of matching on level II occurred. In addition, there was a form of soft coupling of numerical scenarios with qualitative storylines in the form of the integrated scenarios. Simulation results were fed back into the integrated brochure; the simulation results, added numerically, defined simulation inputs and outputs to the raw CIB scenarios and storylines. At the same time, the simulation results were embedded in their—indirect and until this point less explicit—qualitative context assumptions on governance structures, too.

7.6.2 Effects of CIB

The second question of the Lima Water concerned the effects of CIB, focusing on scenario traceability (7.6.2.1), scenario consistency (7.6.2.2) and other effects (7.6.2.3).

Before going into detail regarding the different outcomes influenced by CIB, I summarize what types of effects CIB had during what phases of the Lima Water scenario process. In the Lima Water case, the CIB method (i.e. the method's core) had first-order and necessary effects mainly during the construction of the raw CIB scenarios, which means at the beginning of the combined scenario process, but also at a very few and specific moments during the following phases. The central moment beyond phase 2 was during iteration A (in phase 5), when the CIB balance algorithm was used to test the new scenario C to determine the degree and reasons for its inconsistency. During most later phases, CIB had second-order and somewhat contingent effects through its products (data) and actors. The second-order effects through data occurred mostly through the CIB scenario table that was used in all phases, sometimes intensely. Throughout the process, this table provided the central format by which the scenario sample and the internal structure of individual scenarios could be communicated at a glance. The CIB matrix was used less frequently, central moments were as follows.

- During storyline writing (phase 3*), to check stakeholders' comments from Round Table II against the CIB matrix (Loop II).
- During matching on level I (phase 3), for instance during loop III, to check selected assumptions on interrelations of issue experts against the CIB matrix (with regard to tariffs and green area, e. g.).
- During matching on level II (phase 4), to understand the CIB assumptions behind the descriptor on water consumption in comparison with assumptions made by LiWatool.

Impact diagrams provided by the CIB software were used even more rarely, and when they were used, it was by the CIB scenario experts. This was the case mainly on three occasions.

- To illustrate the balance logic of the (apparently) counterintuitive scenario comprising a private water company and increasing water network losses, and to explain, why all scenarios assume that water consumption is decreasing (for instance during software training sessions in phase 2; and in phase 3* in response to the external comments).
- As a resource to use when writing the long version of the storylines (phase 3*).
- As a tool with which to support the reconstruction of the scenario group's reasonning for modelers and issue experts in phase 3, e. g. during loop III.

The second-order effects through actors occurred mainly through the CIB scenario experts, who, across all phases, acted in the role of CIB advocates, not only by using CIB products, but by repeatedly reintroducing the scenario group's view as stored within the CIB matrix into the process, and by carrying out repeated consistency checks referring to the consistency logic of CIB. Finally, there were *third-order effects* of CIB through scenario products derived from the raw CIB scenarios (that is through the use of storylines and numerical input data) that were *further processed* by the simulation and then used for the construction of the integrated scenarios.

7.6.2.1 Effects on scenario traceability

In the Lima Water case, CIB hat quite considerable supporting effects on the traceability of assumptions on future developments of scenario elements. This supporting effect occurred throughout the process, from the raw CIB scenarios to the qualitative storylines, the numerical input data sets and up to the final integrated scenarios. Scenario *assumptions on future developments* were perceived as traceable, and this can be plausibly traced back to the raw CIB scenarios presented in the form of the scenario table. Still, shared understanding and definitions of scenario elements and their assumed developments had to be reproduced during the later phases by every new actor group coming into the process, namely by storyline writers, modelers, and issue experts.

With regard to the traceability of *assumptions on interrelations* between scenario elements, these were uncovered through the use of CIB, when the group was constructing the CI-matrix. But they were covered again very soon. Starting at the time of the composition of individual raw CIB scenarios and the selection of the sample, they were buried in the matrix again, and were thus accessible more in theory than in fact. This means they were accessible only to those, who understood CIB, and for internals, who knew about the discussions, justifications and perceptions behind the impact assessments, i.e. about the qualitative justifications behind the numbers. The assumptions on interrelations remained covered again, except for select moments, when the CIB-matrix was once more reconsidered (loops II, III and iteration A). Concerning the qualitative storylines, this was due to the length and linearity of the text; concerning the numerical input data sets, these assumptions played almost no role, with the exception of considerations during the quantification of (highly integrated) descriptors like tariffs or green area. With regard to the simulation, they did not play an explicit role as almost no matching on level II occurred. Concerning the integrated scenarios, they were not in the foreground either, but the pure matrix was put into the annex of the brochure. The matrix is provided without textual descriptions—that is to say, assumptions on interrelations are accessible in theory and on the level of formalized impacts only. The excessive use of the CIB scenario table in all phases allowed easy access to and a brief overview of the LiWa scenarios—at the expense of more detailed and rich scenario information (e. g. in terms of qualitative assumptions of interrelations), that soon were buried in the CIB matrix. The individual impact diagrams were only rarely used. In addition, even theoretically possible access to these assumptions was hindered, due to difficulties with the *comprehensibility* of the CIB approach. These difficulties existed even for internal participants like the members of the scenario group, who perceived the correct application of the impact assessment as a hurdle and the standardization convention as a straightjacket. The correct application of CIB thus required the facilitation and help of the CIB scenario experts.

CIB's effect on the traceability of the *composition of scenarios* and of the scenario *sample* seems to have been more limited than expected. With regard to individual scenarios, the fact that the scenario group members had a rather vague understanding of the CIB balance algorithm and that the software was perceived as a black-box play a role. For instance, the members of the scenario group, in spite of their training, did not fully trace the CIB analysis, nor were they all fully persuaded by the explanations of the impact relations behind apparently counterintuitive scenarios, such as those assuming a private water company and a simultaneous increase in water network losses.

Furthermore, *scenario sampling*, the initial one as well as its simplifications, was not—and was not perceived as—a purely method-based and reproducible activity, but instead, was strongly influenced by the scenario experts and considerations of content. Overall, while the LiWa scenario sample itself was at all times accessible through the scenario table (and later in its numerical form as well, in the input and output tables), the justification for its use and the logic of its construction were not accessible. Still, four out of the five in the scenario family were based 1:1 on the internally consistent solutions of the CIB matrix and thus—at least in theory and for experts—traceable.

Finally, the simulation of CIB-based input scenarios through LiWatool might have shed some light on the aim, function and logic of the LiWatool model. The combination of methods thus seems to have had the function of a kind of window on the numerical model which in this case was otherwise perceived as opaque by non-modelers. No systematic and explicit matching on level II of the conceptual CIB model and the numerical LiWatool model was carried out. These insights were therefore limited to a rough idea of the logic of the model, and did not plumb the depths of the internal model assumptions, the calculation of outputs or the additional simulation decisions. These were only uncovered qualitatively, when scenario experts explicitly and specifically asked the modelers to explain them.

7.6.2.2 Effects on scenario consistency

Overall, the use of CIB within the integrated scenario methodology of the Lima Water case did foster the (*apparent*)[397] consistency between different forms of scenarios, namely raw CIB scenarios, storylines, numerical input data sets, simulation outputs, and consequently also integrated scenarios.

It can be plausibly assumed that, with the raw CIB scenarios, a sample of scenarios was constructed and used to structure the following integrated scenario process that—according to the CIB consistency criterion—comprises individual internally consistent raw CIB scenarios, and that these are consistent within the sample, too. These scenario and sample structures (the composition of individual scenarios and of the sample) and the scenario contents (the definition and meaning of scenario elements, direction of and spread between future developments) of the raw CIB scenarios propagat-

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[397] As in all forms of scenarios, the assumptions on interrelations between system elements were not (directly) accessible (see section on traceability above). Content analysis and comparisons were limited to the level of apparent consistency.

ed rather well to the qualitative storylines, to (some degree) to the numerical input data sets, and, for three out of the four scenario families, also to the integrated scenarios**.** Furthermore, overall, there is apparent consistency between the narrative and numerical (input-related) parts of all integrated scenarios.

This rather high level of apparent consistency between the different scenario products can be traced back to two second-order effects of CIB: The use of CIB-generated data (mainly the scenario table) and the work of the scenario experts as CIB advocates, caring about consistency with the CIB descriptor and variant definitions (content level) and with the raw CIB scenario sample (structure level). These effects played out all along the integrated process, as follows.

- During and after storyline writing (and during the integration of comments of external experts).
- During matching on level I, i.e. the translation of CIB raw scenarios into numerical model input.
- During the writing of the integrated brochure.

The use of scenario forms derived from CIB (the storylines and the input data sets) also led to CIB having a third-order effect during the construction of the integrated scenarios. The new scenario C was consciously chosen, as a scenario that was inconsistent in its structure with the internally consistent network constellations of the initial CIB matrix.

The available evidence does not allow a final judgment on whether the use of CIB had indirect effects on the *consistency between models*, that is on the consistency between mental models of participants, the conceptual CIB model and the numerical LiWatool. Still, there is some evidence that—at select moments—a sort of matching on level II between CIB and LiWatool occurred. Still, assumptions on interrelations were far from being systematically or explicitly taken into account, compared and or adapted.

7.6.2.3 Effects on other phenomena

CIB, and with it the CIB scenario experts, had the main influence on the scenario and sample structure—which at times produced tension. On the one hand, the CIB-defined scenarios limited the modelers' autonomy in defining their policy simulations by limiting what policies were plausible under what scenario. On the other hand, there was an apparent tension between the attempts of local stakeholders to appropriate or reappropriate the scenarios, and the activities of the scenario experts, to ensure consistency in terms of CIB. This can be interpreted as a tension between methodological rigor on the one hand vs. local anchorage and ownership on the other hand.

During the Lima Water process, an adaptation of the CIB matrix was refrained from, once a consolidated scenario group based version had been achieved (matrix no. 9). This was due to the anticipated additional effort this would have required, which in part was also ascribed to the systematic character of the CIB. In this context, CIB had itself already been perceived as resource intense (cf. all interviews t1), see also the next section on other factors.

7.6.3 Role of other factors

The third question asked for the factors influencing these effects, namely for the influence of other characteristics of the specific Lima Water methodology (7.6.3.1) and of the specific form in which CIB was combined with LiWatool (7.6.3.2).

7.6.3.1 Characteristics of the methodology

Overall, the social and technical organization and the datalevel had major impacts that contributed to the levels of scenario traceability and consistency as well as to the two further phenomena of disempowering and closure, identified above.

Social organization

In the Lima Water case, the social organization of the methodology strongly influenced and contributed to all effects that, in this synthesis, have been until now attributed to the CIB: The rather low level of expertise and capacities among the participants, with regard to scenario methods and with regard to numerical modeling, influenced the actors' comprehension of CIB and of LiWatool. In addition, the pioneer nature of the methodological combination meant that some actors learned, how to use it only step by step, in the course of the project. Scenario traceability, on all dimensions, was hindered through the lack of inclusion, especially of the modelers, in the CIB, and of the scenario group in the CIB analysis and sampling.[398] Limited inclusion in the CIB also contributed to the phenomenon described above as disempowering. Actors in the role of CIB advocates fostered the scenarios' consistency with the raw CIB scenarios during matching and storyline writing. The close consultations between scenario experts and modelers fostered consistency of input data sets; whereas the final say on the input data sets by modelers was ambivalent from a CIB perspective. Yet the wish of some members of the scenario group, to see their new and less negative scenario "C" within the sample, finally prevailed. This can be interpreted as a successful and ownership generating

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398 The *inclusion of actors* was rather low during the two 'model building exercises': *Modelers* were not included in the group modeling with CIB (nor into the CIB analysis), *scenario experts* were outsiders to num. model building and simulation. Still, the matching part I and the writing of the integrated brochure were joint and rather inclusive activities of modelers *and* scenario experts. The *scenario group's* role was limited to phase 2a and 2c –they came back into the process at the very end only. This limited inclusion certainly limited the possibility of developing a common understanding of the system, especially between modelers and scenario groups, but also between them and other project partners that had not been systematically included in the scenario process. It also hindered reciprocal comprehension of the method and model, and traceability with regard to *internal assumptions on interrelations* (CIB and LiWatool), with regard to the scenario *composition, sampling* and with regard to *simulations* (outputs and additional simulation decisions).

reappropriation of the scenario sample. The fact that the CIB matrix was resistant to adaptations potentially was due to missing method capacities and certainly due to missing resources, which again were linked to the pioneer nature of the process.

Technical design

The technical design of the process had impacts mainly on scenario traceability. The workshop situation of the cross-impact assessment and the intense facilitation through CIB-scenario experts fostered the correct application of CIB. The CIB was implemented in a series of workshops, allowing a form of a *conceptual group modeling* exercise, which was much appreciated by the scenario group (cf. e. g. scenario group member G t1 55, 58 and others). This design made it possible to make mental models and their assumptions of interrelations explicit, as they needed to be justified by facing diverging perspectives on the water system of Lima. On the downside, the *explication and documentation* of the sampling (with and beyond CIB) was not sufficient to reach full scenario traceability for externals—and the *LiWatool simulator* was perceived as untraceable by the non-modelers. In addition, the *participatory character* of the group model behind the CIB matrix was highly valued—higher than comments by externals, which did not lead to adaptations, for instance after RT II. On the occasion of the second potential adaptation of the matrix, this same legitimacy stemming from the scenario group was attributed to the newly proposed scenario C. In sum, not only the systematic and interrelated character of the CIB, but also the emphasis put onto the participatory legitimation of the scenarios—and the missing resources to reach this *within* the CIB approach at the end—hindered the adaptation of the matrix.

Data (cognitive dimension)

The type of data used within the Lima Water scenario methodology had impacts primarily on scenario traceability and to a lesser degree on scenario consistency. As mentioned above, the CIB-generated data and especially the scenario table had fostering effects on both traceability and consistency. These effects were observable more on the level of scenarios and less on the level of models or on the level of assumptions on interrelations, since the matrix itself and the impact diagrams were only rarely used. The lack of access to data hindered scenario traceability: From confidential reports to expert guesses and ad-hoc modeling assumptions as substitutes for nonexistent official data hindered the traceability of assumptions. In addition, descriptor essays and verbal justifications of impact assessment were not made accessible for externals, which was another obstacle to scenario traceability. On the positive side, the integrated scenario brochure was an appropriate means to bring qualitative context assumptions back to the simulation results. At the same time, the narrative scenario descriptions and numerical scenarios became reciprocal benchmarks with regard to apparent scenario consistency—possibly at the expense of the raw CIB scenarios and of the CIB, which requires a more demanding consistency criterion.

7.6.3.2 Form

Overall, the form of combination of CIB and LiWatool had major impacts contributing to the levels of scenario traceability and consistency—and to a lesser degree also to the phenomena of disempowering and closure.

System representation

In the Lima Water case, the CIB represented the overall water futures of Lima in the year 2040 in a qualitative way. LiWatool represented the future technical system developments, including its dynamics over time. The combination of both representations supported scenario traceability. The quantification of the raw CIB scenarios required being more precise in definitions of assumptions on future developments, and at the same time, the CIB-based qualitative descriptions of model contexts and of assumptions between them support the traceability of numerical input data sets. Likewise, time, scenario content and structure that was strongly determined by CIB, restricted policy simulations by LiWatool. The overlap of the two components with regard to water consumption per capita per day made the consistency of underlying models an issue, and would have been an argument for full iteration—which was not carried out for other reasons.

Timing, position and dominance

In the Lima Water case, the CIB analysis and the construction of the Lima in one block LiWatool model were carried out in parallel. Still, CIB somehow came first, since the (first) raw CIB scenarios (summer of 2010: first matrix completed) were ready long before the first simulations were even possible (March 2012: LiWatool model ready for first simulations). Hence, CIB was in the theoretical position to steer the entire integrated scenario process, and it did so effectively with regard to the storyline writing, the definition of input data sets and the composition of the integrated scenarios. In my view, especially the *timing* of the CIB relative to the model building and the dominance of CIB in the integrated scenario process was a precondition for the propagation of the consistency effect and of the rather high degree of traceability of scenario assumptions on future developments in this case, since CIB was streamlining the scenarios. As a counter effect, CIB risked dominating the process, producing a kind of straightjacket, from which modelers and especially the scenario group claimed to be freed.

Link

In the Lima Water case, the link between the CIB analysis and LiWatool was established mainly on the level of scenarios: Model coupling between CIB and LiWatool occurred through *output-input coupling*, using the raw CIB scenarios as a basis for the input data sets for LiWatool simulation runs. This coupling required matching on level I, during which modelers numerically reinterpreted, what the scenario group had qualitatively defined—at times years before. This form of coupling might have helped to propagate the explicitness of scenario assumptions and the apparent scenario consistency to the (first half of) the numerical scenarios and finally to the integrated scenarios. Still, as no systematic matching occurred on level II, the role of CIB with regard to model building and simulation was rather weak: LiWatool, though still under construction during the project, and though it sought to be able to simulate the CIB scenarios, was never openly compared in its structures with the conceptual CIB model. Instead it followed its own logic. This big black box within the integrated scenario methodology was not systematically opened up to non-modelers through any explicit comparison with the conceptual CIB model. I suppose this hindered traceability effects with regard to scenario assumptions on interrelations—and especially with regard to the second half of the numerical scenarios. At the same time, this saved not only an important amount of project resources, but also might have avoided potential consistency conflicts between the conceptual and numerical models, as potentially diverging assumptions on interrelations were simply not revealed.

In addition, resulting scenario forms were coupled in a very soft form through the integrated scenarios. This in turn had beneficial effects on the traceability of assumptions on future developments, since exclusively qualitative assumptions underlying the simulation results also became visible again as context assumptions of the model results. Furthermore, this link supported the apparent consistency between numerical and narrative scenario parts—but had no effects on deeper, that is model-structure- and interrelation-related, levels of scenario traceability or consistency.

Finally, loops during the process were fairly rare, and a full iteration as in SAS did not take place at all.[399] This seems to have been due to the timing, with scenario simulations arriving too late to induce substantial changes. Furthermore, a comprehensive interpretation of simulation results did not occur. Possibly, this was related to the illiteracy of non-modelers with regard to the model, and mainly with regard to the internal model assumptions underlying (also apparently consistent) model results. At the same time, there were no resources to keep the CIB matrix open until the end of the process. This might have hindered a full iteration, too. Finally, the lack of a full iteration could have been an obstacle against higher degrees of consistency between the different scenario forms in the Lima Water case. But this would then have required more intense and systematic comparison and adaptation on the level of model structures (matching on level II).

7.6.4 Central insights

Before concluding this report on the results from the Lima Water case, I would like to emphasize that these are insights from one single and idiosyncratic case. Furthermore, these are insights from the perspective of the combination person, experiencing the pioneer application of CIB within an integrated scenario methodology herself. The Lima Water case was a learning experience for all actors involved. The effective methodology was finally successful in supporting the LiWa team to construct

[399] That means after simulation, the structure of the CIB matrix had not been adapted again in reaction to simulation results.

integrated (qualitative-quantitative) scenarios on Lima's water futures up to 2040. The lessons to draw from this analysis also indicate, what could be done better next time.

Overall, the use of CIB in this form of combination permitted the injection of a certain level of scenario traceability and consistency into the process through the qualitative raw CIB scenarios. To a certain degree, these effects were then propagated into further narrative, numerical and integrated forms of scenarios—but this was not automatic. On the contrary, this propagation required to be actively supported by CIB data and CIB actors, as well as by a suitable social, technical and cognitive organization. These factors seem to be critical for ensuring the inclusion of actors, the comprehension of CIB and the accessibility of assumptions on interrelations as well as the explication and justification of the scenario sampling. All these factors appear to be preconditions to scenario traceability. In turn, scenario traceability then seems to be a precondition for scenario consistency, at least when the CIB consistency logic is used as scenario construction principle. When—as in this case—internal model structures of CIB and of the numerical model are not systematically and explicitly compared and adapted, consistency effects remain on the level of apparent consistency.

The timing of CIB vs. LiWatool posed several challenges. The quantitative reinterpretation of the raw CIB scenarios during the matching that followed the quasi closed CIB analysis had only very little opportunity to influence the CIB (matrix and scenarios), and the merely qualitative definition of the D&V was perceived as not precise enough.

The duration of the process led to changes in the perception of the system under study and to mismatches between the stakeholders' new perceptions and the old system view stored in the conceptual CIB and underlying the strongly structuring raw CIB scenarios.

Furthermore, every time actors were not included in the central activities of the combined scenario process (as in the CIB, in the sampling, in the matching or in the modeling), they found it very difficult to trace the scenarios. It seems doubtful that scenario traceability could have been improved to the point, where it could effectively substitute for participation.

Overall, the case study revealed two open questions concerning this type of CIB&S methodology: First, the matching on level I might perhaps be better organized in close connection with the CIB analysis. Second, until now, no systematic and explicit techniques or practices have been developed to ensure an adequate matching on level II. Furthermore, the case study points out a certain tension that the fact of using CIB in the position of a steersman to determine scenario content and structure can pose the risk of disempowering the other actors in the process and of straightjacketing the entire combined scenario process. Finally, the case study has generated new open questions, such as: What possible form of full iteration (as in SAS) is at all realistic and appropriate in CIB&S designs?

Chapter 8: Cross-case interpretation and discussion

In this chapter, I interpret, synthesize and discuss the results from both case studies. First, I compare and contrast the results with each other and with my initial expectations. The empirical deviances from my initial expectations make it possible to learn about other factors that are hindering and supporting the effects of CIB in combined scenario methodologies. Across both rather diverging cases, I observe rather similar patterns of these factors (8.1). Second, to answer the research questions, I present overall insights on the effects of CIB in different forms of combined scenario methodologies (8.2). Third, I discuss and refine the conceptual framework (8.3). Finally, I confront my findings with the state of research on CIB and on combined scenario methodologies, and embed them in the current debate on quality in futures research (8.4).

8.1 Cross-case results

In the following, I sum up the results from the cross-case analysis, that is the comparison of similarities and differences between the UBA and Lima Water case.[400] First, I briefly sum up the different contexts and framings of both cases, which also resulted in rather different methodologies and forms of CIB&S. I argue that both cases can be considered prototypes, standing for a typical function that CIB can take over in combined and integrated scenario methodologies (8.1.1). Then, I demonstrate that the empirical results with regard to effects of CIB *and* with regard to other factors for these effects are fairly similar across both cases. These findings are contrasted with my initial expectations (E1-E13) (8.1.2).

8.1.1 Two prototypical forms and functions of the use of CIB within combined scenario methodologies (type CIB&S)

The two CIB&S cases of this study are very different with regard to their contexts and with regard to the phenomena themselves, i.e. with regard to the individual application of CIB within the two hybrid scenario methodologies. In this section, I argue that the very different contexts and framings of both cases also result in very different combined forms and very different methodologies. In the following, I argue that each of the cases has a prototypical character for the use of CIB within combined scenario methodologies, namely with regard to the function of CIB: The UBA case stands for a use of CIB to provide (harmonized) context assumptions to a model group and the Lima Water case for the use of CIB to construct integrated system scenarios.

400 For the possibilities and limits of drawing conclusions from the comparison of these two unique cases, see also chapter 5.

8.1.1.1 Two rather different contexts and framings

There are some similarities with regard to the contexts and framings of the two cases that need to be considered, as they could explain similarities in the methodologies and their effects. With regard to their project context, both cases are embedded in public research projects funded by German federal ministries; both projects have an inter- and even transdisciplinary nature, when it comes to issues and participants. With regard to their immediate context, in both cases the CIB scenario experts were researchers from ZIRIUS, who had a fairly strong methodological interest in CIB and its combination with numerical modeling and simulation. Two of these scenario experts, including me, have contributed to both cases, thus the same actors with the same mind sets had an impact on both processes.[401] Furthermore, in both cases the CIB method was used with the aim of performing a systematic construction of (context) scenarios.

Otherwise, the two cases differ considerably in their project contexts with regard to the size and nature of the project (the small demonstrator UBA project with two partners vs. the large and applied megacity LiWa project with a large number of partners), with regard to their duration (5 months for the UBA project vs. 5 years for LiWa), with regard to their immediate contexts, with regard to their framing, their available resources, their aims, and their use of the scenarios. In the UBA case, the CIB application was a method demonstrator in a very small project—in which interest in the method seems to have outweighed considerations of content. The Lima Water case on the other hand was a full pioneer CIB&S process embedded in a larger research project—in which methodological interests were at play too, but these were only one aim among other, more content- and application-oriented aims. In both cases, CIB was used to construct scenarios. In the UBA case, CIB was used for a systematic construction of numerical context scenarios for Germany 2030 (and to familiarize experts at UBA with the method); for the Lima Water project, CIB was used as a technique with which Peruvian stakeholders could perform systematic group modeling and construct qualitative scenarios of Lima's water futures in 2040—scenarios that have been further processed to become integrated systems scenarios—and to carry out a pioneer application of CIB&S. The intended and effective function of CIB&S was different in the two cases. In the UBA case, CIB was used within a combined scenario methodology to serve the analysis and potentially also the comparison and harmonization of context assumptions of model-based scenario studies. In the Lima Water case, CIB was used within a combined scenario methodology to serve the construction of integrated (qualitative-quantitative) scenarios.

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[401] I suppose there were also learning effects between both projects.

8.1.1.2 Two rather different combined scenario methodologies using CIB

The different contexts and framings also resulted in rather different processes, methodologies and forms of the combination.

Processes

By comparing both processes we can determine the following: In the UBA case, a minimal form of CIB&S process was carried out. Through its quantitative character, the CIB scenario construction (phase 2) was fully merged with the matching (phase 3). Simulation and iteration (phases 4 and 5) were anticipated, but not carried out. In the Lima Water case on the other hand, a full CIB&S process, covering the six phases of the ideal type process scheme was carried out. In addition, LiWatool was newly built in parallel to the CIB analysis, a specific storyline phase was realized, and the iteration phase was added by integration, merging numerical and narrative scenarios into integrated scenario representations. Finally, several loops and iterative activities occurred, although no full iteration as in SAS.

The CIB analysis was implemented and designed differently with regard to the selection of D&V (phase 2a) in both cases (literature-based vs. workshop-based, although both approaches made use of experts) and with regard to the cross-impact assessment (phase 2b) (individual interviews, in part covering partial matrices only, plus workshop vs. a series of group workshops to fill the entire matrix jointly). Still, the CIB scenario analysis and sample selection (phase 2c) was in both cases carried out through the CIB scenario experts using the CIB software, with one of the scenario experts involved in this analysis during *both* cases. CIB results were presented in the form of products to the scenario groups in both cases.

Methodologies

Comparing the methodologies of the two cases shows the following.[402] Overall, the scenario process in the UBA case was mono-linear and condensed, whereas in the Lima Water case, two parallel streams of activities, namely CIB and storyline writing on the one hand and model building and simulation on the other were linked through the matching in phase 3, occurring *after* the CIB, and through integration in phase 5.

With regard to the *technical design,* in the UBA case, CIB was used to process typical input data of (anticipated) client models. In the Lima Water case, CIB was used to construct scenarios that were effectively translated and then simulated by LiWatool'. CIB and numerical models played the following roles: In both cases, CIB has directly structured the construction of (raw) CIB scenarios. There have been some differences in the CIB method application: First, verbal justifications of impact as-

[402] Please reconsider Figure 18 and Figure 23, showing visual summaries of the CIB&S methodologies of the UBA and the Lima Water case.

sessments were, in the UBA case, only for selected impacts and ex post, reconstructed by the scenario experts and only documented in the form of selected impact diagrams. With regard to this aspect, the LiWa project learned from the experience in the UBA project, and therefore, justifications were systematically and directly documented in parallel to the workshops (again mainly through the scenario experts). Second, the standardization convention was applied in the Lima Water case, but omitted in the UBA case to facilitate the task for the UBA expert scenario group. Furthermore, in the LiWa case, CIB then had further indirect impacts through the use of CIB generated data (especially the scenario table and to a lesser degree the CIB matrix) and even more indirect impacts through the use of CIB derived scenario products (storylines and input data sets) as well as during the integration and iteration phase for structuring the integrated scenarios and for testing a newly proposed scenario.

In both cases, numerical (simulation) models played a role as clients for context scenarios provided by the CIB, and also as supply models, providing the process with data as time series on alternative future developments. In the UBA case, (rather theoretically) client and supply models (from in- and outside of UBA) played a role: The clients through their input data needs (indicators), the suppliers' by providing time series for different future developments, resulting from their calculations and simulations. In the Lima Water case, the LiWatool model, newly developed in parallel to the CIB&S process, was steering the matching indirectly through its (indicator) needs (and at times in response to simulation results) and used the input data sets derived from the raw CIB scenarios for its simulation runs. These input data sets were, also in the Lima Water case, in part fed by modeling and simulation results of other models, as for example with regard to the information on possible future climate and river flow variations in the catchment areas. In both cases, a variety of further methods of data collection and analysis were applied (as desk research, interviews and workshops) as well as facilitation, training and also at times negotiation—but with different emphasis and intensities, linked to the different duration, resources and aims of the processes.

With regard to the *social organization*, the UBA case was characterized by a coalition of (method) interest between scenario experts and the UBA project management. The Lima Water case was characterized by complex and multiple interactions of modelers and scenario experts, with nevertheless at times low inclusion and unclear responsibilities concerning the method combination. Both cases have been influenced by the scenario experts, researchers from ZIRIUS. They were the 'method persons', representing, facilitating and at times defending the CIB and the combined approach.

Both *scenario groups* comprised actors beyond research, the UBA scenario group members are academics in a the role of environmental policy advisors for the Federal Government; the Lima Water scenario group members have a larger range of backgrounds and at least some of them clearly are not only local experts, but also stakeholders with specific and contrasting interests (NGOs vs. water company).[403] With regard to cooperation, in the UBA case, scenario experts and scenario group are doing the CIB analysis and matching jointly and 'in one'. In the Lima Water case, the scenario group is included in phases 2 and 5 (and here only into the step of iteration). Also in both cases, the CIB analysis and the scenario sampling have been mainly carried out by the scenario experts, not actively including the respective scenario groups. In both scenario groups, the competence of using the CIB software was low, despite theoretical access in both cases and despite additional trainings in the Lima Water case.

Modelers were only indirectly included in the UBA case in the form of those members of the scenario group, who are environmental modelers themselves, or who work closely together with them and/or represent them. Second, modelers' ideas and assumptions on future developments were very indirectly included, as the process heavily relied on model outputs and on anticipated model (input data) needs. In the Lima Water case, modelers were not directly included in the CIB either, but played the decisive role during model building and simulation. Matching and integration were joint activities of modelers and scenario experts.

With regard to the *cognitive or data dimension*, the UBA case realized a qualitative analysis and synthesis of quantitative model input. The Lima Water case realized the integration of qualitative scenarios and their quantitative reinterpretation and analysis. The data used in both processes came from heterogeneous sources as model information, literature as well as expert assessments and expert guesses. In both cases, for matching, actors used pre-existing numerical formulations of future developments—as far as readily available. In the UBA case, all D&V had been selected with regard to this criterion and only very few additional ad hoc decisions were made. On the contrary, in the Lima Water case, data availability was not a criterion during the selection of the primarily qualitative D&V. In consequence, much of the numerical data was newly generated either through research within the project or through expert guesses by modelers, scenario experts and issue experts. In both processes, a form of descriptor essays played a role to document assumptions on system elements and their future developments. In the UBA case, they were mainly used for a short definition of indicators and time series chosen. In the Lima Water case, they were used to store qualitative information on descriptors and variants including assumption on interrelations. Documentation and justification of numerical versions was attempted but not completed for all descriptors.

In sum, in both methodologies, actor- and method- driven activities were combined. In both cases, pure (automatic and reproducible) the methodological impacts on activities fell behind the more

403 In addition, there was some fluctuation (non-continuity) among scenario-group members in the UBA case and more continuity in the Lima Water case.

important impacts of the actors—who also affected the activities through the choice and implementation of methods. Despite all differences, the central similarities are the use of CIB and the impact of the scenario experts.

Forms of the combination

Overall, two rather different forms of the combination of CIB with numerical models were realized in both cases. [404] With regard to the *system representation*, the cases diverged considerably: In the UBA case, the CIB was used for a qualitative systems analysis of numerical model assumptions on future social contexts. It thus provided a conceptual model of numerical parameters that were mainly *exogenous* to the anticipated client models, covering systems embedded in these contexts. In the Lima water case CIB synthesized qualitatively described factors affecting the water future of Lima, providing not only a conceptual *context* model, but also a very much simplified *system* model (covering technical dimensions, water consumption, e. g.), and including a (rough) description of policies. LiWatool then analyzed the technical water system embedded in these social, political, environmental and institutional contexts in a numerical way.

In the UBA case, the *position* of both components to each other can be characterized as *models first,* since models pre-existed the CIB analysis (timing) and also strongly steered the content of the context scenarios. The CIB had the task of structuring and bundling the data that was strongly predefined by the client and supply models (dominance) (for more detail cf. chapter 6). In this form of combination, the models would, if there was a reciprocal comparison, provide the benchmark for adaptations.[405]

The Lima Water case is more of a *CIB first case:* Even if the central numerical models were newly built in parallel to the scenario process, the CIB scenarios were ready before the matching and simulation were (timing). In addition, CIB, in the hands of the scenario experts and the scenario group, determined the entire process of constructing scenarios insofar as it involved scenario content and structures. Also, the raw CIB scenarios were used as a benchmark for comparison and adaptation (dominance). Still, a construction of the numerical scenarios by CIB and LiWatool together occurred through the joint activities of scenario experts and modelers with, finally, the LiWatool model and modelers dominating the matching activity (model requirements and needs) and the simulations.

Overall, and despite the apparent divergences concerning the positions, in both cases, numerical models provided numerical scenario content (even if they were far from being alone in this role in the Lima Water case) and the CIB had the major say on scenario structures and scenario sampling.

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404 Please reconsider Table 18 (UBA) and Table 28 (Lima Water), summarizing the forms of the combination.

405 Models were supplying indicators, time series and might, in a full application, also provide assumptions on interrelations to be integrated into the CIB.

In the UBA case, the front-end *link* between CIB and numerical client models was anticipated only—back-end link to the supply models was at times not even explicit. No iteration occurred. A soft link from the numerical indicators and time series building the D&V structure of the CIB to underlying more qualitative ideas on possible future developments was established in the descriptor briefs. Overall, some form of qualitative reinterpretation of numerical input data occurred during the process. Still, the CIB itself was conducted in a quantitative form from the very beginning with qualitative aspects in the background only. In the Lima Water case, links were mainly established on the level of scenarios. There was back-end (output-input) coupling from CIB through matching to LiWatool. In addition, there was an explicit soft link between simulation results with narrative context descriptions within the integrated scenario. Throughout the scenario process, through matching and simulation, a quantitative assessment of qualitative scenario assumptions occurred. With regard to iteration, two of the loops during the process did concern the relation between CIB and LiWatool (loop III and IV, i.e. the loops to and from matching). The numerical input data sets were the direct communication instruments between CIB and LiWatool. Matching on level II did not occur explicitly or systematically; it remained unclear how much impact the combination in fact had on the level of (internal) model structures. Finally, a full iteration in the sense of SAS was not carried out. The final iterative steps remained on the level of the apparent structure of the scenarios, but the CIB matrix (and hereby the structures underlying the scenarios) was not affected.

A central similarity of both cases is that model building and simulation one the one hand, and the CIB analysis on the other hand were rather separate activities, each one rather excluding the respective main actors of the other activity.

8.1.2 Effects of CIB and of other factors: evidence vs. expectations

The empirical findings of both cases with regard to effects were compared with each other and with the initial expectations E1-E13 (see section 4.5). To avoid repetition, the following section does not discuss the expectations from E1 to E13 one by one, but rather analytically regroups results into four aspects. First, in both cases, scenario traceability was lower than expected. I argue that, again in both cases, CIB and other factors of the methodologies contributed together to this result in a comparable way (8.1.2.1). Second, results with regard to scenario consistency of both cases were complementary; the effects of CIB and the influences of other factors seem comparable, too (8.1.2.2). Third, rather similar other effects were found in both cases and the respective interplay of CIB with other factors also shows similar patterns (8.1.2.3). Finally, the role of the form of combination is critically discussed in the light of the empirical evidence from both case studies: The 'degree of integration' is identified as the central factor for effects of CIB on traceability and consistency.

8.1.2.1 Patterns of scenario traceability (“T” and ”R”)

First, the scenario traceability reached in both cases is compared. Then, these findings are used to revise the initial expectations on effects of CIB and of other factors, see expectations “T” E 1—E 6 and “R” E 13 in 4.5.2. The renewed picture of the traceability effects of CIB is more cautious and better informed about their methodological conditions.

Degree of scenario traceability

Table 38 summarizes the scenario traceability that was reached in the UBA and Lima Water cases.[406] The degrees of scenario traceability reached per dimension are quite similar across the two cases.

Table 38: Degree of scenario traceability (UBA and Lima Water)

My assessments on a 6-point scale: 1=very low, 6=very high; across actors and across forms of scenarios

cases *dimension*	**UBA**	**Lima Water**
Assumptions on future developments	5= high	5= high in all forms of scenarios
Assumptions on Interrelations	For externals or non-experts 2= low For internal method experts: 6= very high	For externals or non-experts 2= low For internal method experts: 6= very high
Composition of indiv. scenarios	For externals or non-experts 3= rather low For internal method experts: 6= very high	For externals or non-experts 3= rather low For internal method experts: 6= very high
Scenario sampling	3= rather low, for experts only	1= very low, for internal experts only

Overall, in both cases, across actor groups and across the different forms of scenarios (raw CIB scenarios as well as in the derived narrative, numerical and integrated scenarios in the Lima Water case), assumptions on future developments were perceived as highly traceable—as I had expected. In contrast, but again in both cases and across different forms of scenarios, the traceability of assumed interrelations and of the composition of individual scenarios and of the sampling were perceived as (rather) low, at least by non-experts and externals. In sum, traceability was assessed as lower than I had expected it to be in a combined scenario methodology using CIB. In what follows, I will discuss why this is the case and why this is the case in *both cases*.

Effects of CIB and their interplay with other factors (“T” vs. “R”)

In each of the cases, the degree of traceability was analyzed in relation to the respective methodology. This allowed the traceability results to be individually interpreted and qualitatively explained. The cross-case analysis shows rather similar patterns, namely rather similar (non-)traceability effects of CIB (see “T” E 1-6) in a (rather similar) interplay with a multitude of other factors (see “R” E 13) in both methodologies.

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406 For more detail, see sections 6.3 and 7.3 above.

Understanding CIB is not trivial, but rather a precondition for perceived traceability effects

The CIB method was assessed as rather difficult to understand (Lima Water) and as comprehensible but not easy (UBA). Members of both scenario groups (that is internals) had similar difficulties with the CIB method. They had trouble with the repetitive character of the systematic consideration of pairwise impacts; with the logics of the impact assessment, since respecting the direction of impacts and assessing direct impacts only were perceived to be a hurdle that participants had to overcome to apply CIB without mistakes; they developed a roundabout, or vague, understanding of the consistency logic only; and, in the Lima Water case, perceived the application of ScenarioWizard as something of a black box**,** despite repeated software training sessions. The standardization convention, applied in the Lima Water case only, seems to have been an additional barrier to understanding and accepting CIB—but at the same time a safeguard against a bias towards positive impacts (cf. also 8.1.2.3). In both cases, it seems that fully understanding CIB is the precondition to fully benefiting from the effects of CIB on traceability – a condition that holds for internal as well as for external actors.

Using CIB promotes highly traceable scenario assumptions on future developments—an effect which is reinforced by the quantification of D&V

In both cases, the assumptions on future developments were perceived as very traceable. This can be plausibly traced back to the fact that the systematic CIB requires precise definitions of the D&V, and to their documentation in CIB-generated data, namely the matrix and the scenario table. In addition, traceability of assumptions on future developments was, in both cases, supported by the *numerical* definition of future developments. In the UBA case this was the main definition, supplemented through verbal and visual explanations in the descriptor briefs. In the Lima Water case, it was additional scenario information, made accessible through the integrated brochure and the simulation input and output tables across scenarios.

Using CIB reveals assumptions on interrelations, but it is difficult to keep them open and accessible

The cross-impact assessment and (especially the workshop-based parts of) the building of the CIB matrix in both cases helped to make the mental models of the participants explicit and thus supported the explicitness of scenario assumptions on interrelations. But—again in both cases—this effect was limited to internals, meaning to participants, who were able to access and understand the CIB matrix. In both cases, the access granted to externals was more theoretical than real. Neither the systematic documentation of verbal justifications of impacts nor the impact diagrams were fully used in the communication of scenarios to externals in the Lima Water case. (Impact diagrams were included in the final report of the UBA project, and there they were assessed as being more understandable and accessible than the matrix itself.) Instead, especially in the Lima Water case, the heavy use of the scenario table throughout the process—however much it may have fostered the explicitness of assumptions on future developments and the accessibility of the scenario sample's structure—covered the assumptions on *interrelations* that were stored—or buried—in the CIB matrix.

Effects of CIB on the traceability of the numerical input data sets diverge due to the differences in the methodologies in the two cases: In the UBA case, the CIB was carried out using numerical indicators and time series directly (to be potentially used by the models as input data). Therefore, this CIB exercise has shed a direct light on this (potential) model input with regard to the assumed interrelations between different indicators and has made them explicit within the CIB matrix. The UBA case had, so to speak, the advantage of having the numerical formulations of the D&V ready during the CIB, and the disadvantage that no other qualitative intermediary system elements were taken into account. In the Lima Water case, CIB traceability effects have been handed down to storylines and to the input data sets (second-order effects). But these two derivative scenario products did not inherit the traceability of the raw CIB scenarios when it comes to interrelations. With regard to the storylines, this was mainly for reasons of the length and linearity of the text. With regard to the numerical input data sets, this translation into numbers happened ex post only. Modelers were not included in phase 2. Thus, the translation required the reconstruction of the scenario reasoning through the modelers. This happened in some form of ex-post cognitive integration, during which only selected assumptions on interrelations were reconsidered. On the positive side, this ex-post translation was possible to a certain degree.

Insufficient understanding of CIB and inaccessible sampling decisions hinder traceability of scenario composition and sampling

In both cases, scenario composition and sampling remained only partially traceable even for internals (esp. for the scenario groups), due to limited understanding of the balance algorithm and the perceived black-box character of the application of the scenario software. In the Lima Water case, in addition, the scenario experts' subjective impact on the scenario sampling beyond pure methodological decisions remained disguised, not only from externals, but also from members of the scenario group and to the modelers. In addition, the sampling was not fully transparently documented in the scenario brochure. In the UBA case, for external CIB method experts, the sampling is at least theoretically accessible, as it is fully documented in the final report. The acceptance of the sample even for internals thus still depended on the trust in the CIB method—its software and those handling it. Trust in the scenario experts and in the scientific aura of CIB seems to be a substitute for traceability, as the UBA case suggests. In the UBA case, the sample was fully accepted and CIB benefited from the academic legitimacy of the systematic approaches.

Linked to this, ownership issues arose in the Lima Water case, leading to the reappropriation of the scenario sample by the scenario group. The scenario group was not fully included in the construction of the sample in the first place and was also excluded from the continued processing of the scenarios through the numerical side of the integrated processes.

Ambivalent role of scenario experts: facilitators and trainers of CIB but also masters of the CIB analysis and the scenario sample

Furthermore, in both cases, the scenario experts played an ambivalent role with regard to scenario traceability: On the one hand, they facilitated the CIB application and trained the scenario groups (e. g. in using the software in the Lima Water case) and thus, played an important role in supporting the understanding of CIB. On the other hand, they remained the masters of the CIB analysis and were the ones deciding about the scenario sample through their interpretations of the content.

Limited effects of CIB with regard opening the black box of the numerical models

Scenario traceability, in both cases, was challenged by implicit and/or inaccessible model assumptions on two levels: There were limitations in access to both 'assumptions behind input assumptions' and to internal model assumptions.

In both cases, the access to *assumptions behind assumptions* was a challenge, especially with regard to the access to assumptions behind time series and behind (input) data that was provided by some sort of external supply model. This traceability was strongly dependent on the kind of documentation that was provided with this (external) data.

With regard to *internal model assumptions of numerical models*, in the Lima Water case the simulation of CIB-based input scenarios through LiWatool seemed to shed some light on the aim, functioning and logic of the LiWatool model itself. Prior to the scenario simulation, this model had been perceived as a black box by the non-modelers, especially by the scenario group. This means the method combination seems to have had some sort of window function with regard to the numerical model. But, as no systematic and explicit matching on level II between the conceptual CIB model and the numerical LiWatool model occurred, this insight was limited to a rough idea on the models' logic. It was not going into the depth of internal model assumptions, calculations of outputs and additional simulation decisions. These were only (qualitatively) uncovered at specific moments when scenario experts in their role as CIB advocates explicitly and specifically asked the modelers to explain them. In the UBA case, the (hypothetical) need for some sort of matching to uncover internal model assumptions was seen for all deeper forms of harmonization, i.e. harmonization going beyond the soft comparison of input data sets. This was considered necessary especially in cases of overlap, in which models are simultaneously in the role of client and supply model within a model group, which is linked through harmonized context scenarios (see also the consistency of underlying models in the next section).

8.1.2.2 Patterns of scenario consistency ("C" and "R")

First, the scenario consistency reached in both cases is compared. Then, these findings are used to revise my initial expectations on the effects of CIB and other factors, see expectations "C" E 7-10 and "R" E 13 in 4.5.2. This allows me to paint a more differentiated picture of the consistency effects of CIB and their methodological conditions.

Degree of scenario consistency

Table 39 gives a rough overview of the scenario consistency reached in both cases. [407] These degrees of consistency are comparable with regard to the levels covered by both cases.

Table 39: Degree of scenario consistency (UBA and Lima Water)

My own assessments on a 6 point scale: 1 not given at all, 6 fully given; across actors and across forms of scenarios; consistency criterion of CIB, if not indicated otherwise.

cases *level*	**UBA**	**Lima Water**
Internal consistency	6= fully given	5= given across all forms of scenarios except for 1 out of 4 scenarios
Consistency within	6= fully given	4= rather given, as except for 1 out of 4 scenario families
Consistency between different forms of scenarios	*(does not apply)*	4= rather *apparently* given across raw, narrative, numerical (input side) and integrated scenarios
Consistency of underlying models	*neither systematically nor explicitly compared nor adapted)*	2= rather not given

Corresponding to the assumption A3, the internal scenario consistency as well as consistency within the sample of raw scenarios—both according to the consistency criterion of CIB—are fully given in both cases. In the Lima Water case, this holds true for all forms of the scenarios, namely raw CIB scenarios, storylines, numerical input data sets as well as integrated scenarios, but with the exception of one of the four scenarios. Still, consistency between the content and structure of these different forms of scenarios is ensured on the level of *appearance* only, because assumptions on systemic interrelations have been covered again. Furthermore, the consistency of the underlying models is cautiously estimated as being rather not given in the Lima Water case. In the following section, I discuss, how the empirical findings can be explained through the interplay of CIB with other factors of the methodologies.

Effects of CIB and their interplay with other factors ("C" vs. "R")

The degrees of consistency were put into relation to the methodologies.[408] The cross-case analysis—as far as applicable—shows fairly comparable patterns, regarding the consistency effects of CIB (see

407 For more detail, see sections 6.4 and 7.4.

408 Since in the UBA case, no full CIB&S process was carried out, the empirical evidence for some of the consistency levels is limited to the Lima Water case and to hypothetical considerations based on the UBA case.

“C” E 7-10) and the interplay of CIB with a multitude of other factors of the methodologies(see “R” E 13), which are similar in both cases.

Correct application of CIB allows direct effects on internal consistency and consistency within the raw CIB scenario sample

In both cases, the correct application of CIB and its balance algorithm were ensured through the scenario experts and the use of the CIB software. Therefore, for both cases, I assume that the resulting (raw) CIB scenarios are internally consistent according to CIB. In addition, since the sets of CIB scenarios result in each case from the same respective CIB matrix (assuming the same interrelations under the same level of consistency), I assume that there is consistency within each of the samples, too. This also means, the individual scenarios of one sample are consistent with each other with regard to the systemic logics justifying them. Strictly speaking, in the Lima water case this holds true for scenarios assuming the same climate variance only.

Research need: Does consistent according to CIB equal subjectively perceived as consistent?

Do the (individual) process participants consider the raw CIB scenarios resulting from the CIB analysis to be consistent? Are the scenarios that are based on the joint CIB matrix and retrieved with the help of the systematic CIB consistency criterion perceived as making sense with regard to their overall mental models of future developments and as matching with their subjective and holistic consistency perceptions? These issues have not been systematically analyzed in this study. Since evidence from the two cases points in different directions,[409] it is an open question whether and under what conditions the internal consistency of the CIB scenarios based on the systematic CIB criterion meets the

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[409] In the UBA case there are hints that the CIB consistency criterion was accepted (even by those, who did not fully understand it). Furthermore, there was no opposition or protest from the participants with regard to the resulting scenarios/ or sets of context assumptions. In addition, in the final presentation, an intuitively composed set of assumptions (those considered to be the most likely ones) was tested with regard to its consistency with the CIB matrix. The consistency check with CIB has shown that four out of the ten descriptor variants in this constellation were inconsistent; this demonstration seemed to be accepted by the participants. Potentially, the scientific credibility assigned to the CIB method and the noncommittal ‘demonstrator character’ of the results contributed to this effect.
In the Lima Water case, the issue of counterintuitive scenarios came up repeatedly, especially with regard to those scenarios that assumed a future that included a private water company as well as increasing water network losses. Despite demonstrations of the CIB reasoning with the help of the impact diagrams, individual members of the scenario group continued to disagree with the plausibility of this type of scenario (cf. interviews expert I t1 to t3, FN October 2012). Furthermore, in the Lima Water case, even if participating actors developed some sort of shared understanding of the problem over time, there were hints that not all mental models of modelers, issue experts, external experts and all scenario-group members were perceived as being consistent with the CIB matrix. (This matrix had be jointly constructed and contained various decisions on impacts based on group compromise, see e. g. loop III). This became apparent especially at the end of the process when, due to its duration, the participants’ perceptions of the system no longer matched the CIB model (see the reappropriation of the sample through the reformulation of scenario C by the scenario group).

intuitive consistency perception (meaning the gut feeling or subjective consistency) of the members of a scenario group and of external readers of scenarios.

CIB fosters (apparent) consistency between different forms of scenarios—supported by CIB data and actors

This issue was subject to analysis only in the Lima Water case,[410] in which, based on the raw CIB scenarios, further scenario forms were derived, namely storylines, numerical input data sets, simulation outputs and finally also integrated scenarios. The propagation of scenario consistency through the scenario process is not automatic, but *CIB-generated data* and *CIB actors* played an important role in fostering the second-order consistency effects of CIB. In addition, the later use of the derived scenario forms derived from CIB (storylines and input data sets) allowed important third-order consistency effects of CIB on the construction of the *integrated* scenarios.

Hypothetical effects of CIB on consistency between input data sets of different (client or supply) models

In the UBA case, CIB was applied to construct input data sets that could be used to compare, or even to adapt, and potentially even to harmonize input data sets of different client models of an entire model group of supply and client models. In the Lima Water case, this did not apply, since with LiWatool, only one client model used the CIB-based input-data sets. The UBA case delivered the desired proof of concept: proof that it is possible to generate internally consistent sets by bundling and structuring currently used input information with the help of CIB. But any attempt to use the approach to support the harmonization of model groups requires much more, namely the commitment of the modeling groups to deal with two further issues of consistency. First, the *consistency between input assumptions used by several different client models* becomes an issue: Are models so specific that input data sets need to be constructed individually for single models rather than for a model group? How are solutions found in a model group to the use of different indicators by different models? How strictly do different models need to stick to the pre-defined and CIB based input data sets? Second, consistency between framework assumptions of data coming from supply models and assumptions of the CIB underlying the input data sets taking up this data, that is so to speak *consistency between* '*assumptions behind assumptions*' becomes an issue. In both cases, (numerical) data provided to the numerical input data sets (based on CIB scenarios) was based on modeling and simulation and thus on further (often implicit and non-transparent) framework assumptions. In the UBA case, I have concluded that a non-demonstrator application of CIB&S would have required to access and assess these underlying assumptions. In the Lima Water case the same issue came up, since the reasoning behind some of the externally provided data (model and not model-based) was inaccessi-

[410] Therefore, special caution applies with regard to generalizations.

ble. Other numerical data provided by distinct supply models (e. g. external demographic models or the climate models) were themselves based on explicit framework assumptions. For example the climate models were based on the IPCC SRES storylines. Even these explicit framework assumptions, underlying the data that was provided by the internal catchment modelers, were not systematically checked against the LiWa scenarios. Instead they were assumed to be consistent, due to their global character.

The obstacles of matching on level II hinder consistency between conceptual CIB model and mathematical models

The UBA case pointed out that using CIB to support the consistency between context assumptions of client and of supply models, seems to be demanding on the level of the social and technical organization. Further complexity arises when models are simultaneously supply *and* client models for some of the indicators included in the same CIB generated input data sets. Every client model can also serve as a supplier model to fill in assumptions on interrelations into the CIB network. Therefore, one should make sure to integrate available model information on interrelations into the CIB-matrix to avoid mismatches between (expert-guess based) CIB assumptions and model assumptions on interrelations.

With regard to the issue of consistency between the conceptual CIB model and numerical (simulation) models, both cases provide hints that a systematic comparison and adaptation of internal assumptions on interrelations between the CIB model and the numerical models, that is the matching on level II, is rather challenging. My initial expectations (E6 and E9) were rather naïve. In the Lima Water case, only at selected and unsystematic moments did a sort of tacit matching on level II between CIB and LiWatool occurr: Assumptions on interrelations were far from being systematically or at least explicitly considered, compared or adapted. This was hindered by the following factors.

- The division of labor between the modelers on the one hand and the scenario experts and the scenario group on the other.
- The complexity of internal model structures of the mathematical model.
- The model illiteracy of non-modelers and the CIB illiteracy of the modelers.
- The high resource needs and the lack of solutions for an appropriate social, technical and cognitive organization of such an approach, e. g. allowing, to the necessary degree, the reciprocal inclusion of actors into the respective activities.

To effectively use CIB as a joint conceptual model, these and other open issues still need to be clarified. The evidence from both cases does not allow me to judge, whether in addition to consistency effects between a conceptual CIB model and numerical models, the consistency of inner model structures of several numerical models could be increased through the use of a CIB in the form of a joint conceptual (context) model.

8.1.2.3 Patterns of other effects ("X" and "R")

Initially, other effects of CIB were left open to empirical exploration, see expectation "X" E 11. And indeed, in both cases, the other (unintended) effects of CIB were found inductively. Even if these were not identical, they seem to point into comparable directions. In addition, the patterns of interplay between CIB and other factors of the methodology were comparable, too.

The clash (UBA) and the disempowering (Lima Water): CIB and the social organization of integrated scenario methodologies

In both cases, there were hints that through the use of CIB in combination with numerical modeling and simulation, long-standing practices and roles, responsibilities and the distribution of tasks might need to change: The clash of CIB with modeling practice (see UBA, chapter 6.5) and the disempowering of modelers and of the scenario group (see Lima Water, chapter 7.5) are, in my view, closely related expressions of this effect. Classically, the *modelers* are accustomed to selecting the content and structure of input data sets for their models themselves and they are used to doing so (at least at times) in function of model results. In a methodological setting comprising CIB, they have to give up this impact on the model input (first half of numerical scenarios), and in consequence, also lose this indirect influence on the output of their numerical scenarios (second half of numerical scenarios).[411]

In parallel, the role of the *scenario group* was, in both cases, mainly focused on the provision of expert assessments of pairwise interrelations—they did not directly decide upon or select a sample of scenarios. Neither the UBA experts nor the Peruvian stakeholders engaged in much discussion of the comprehensive pictures of future developments. Instead, through the CIB method, they were guided to focus their discussion on a very short list of system elements with a small variety of future developments each, and on pairwise influences between possible future developments. The discussion was thus brought down to small analytical segments of possible futures. The *synthesizing* task—in contrast to the *analytic*al one of the scenario group—of constructing scenarios and selecting a sam-

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[411] In the UBA case, the application of CIB was somehow clashing with the current modeling practice comprising a numerical (model-based) scenario culture, i. e. scenario building based on quantitative information, available data, modeling traditions of using specific indicators, and conventional and shared assumptions on future developments from high credible sources including the consideration of rather small bandwidths of future uncertainty and the definition of input data sets by autonomous model groups. In the Lima Water case, the modelers did perceive the external expertise on model contexts as helpful, but accepting these scenarios as model input was very restricting to them, too. And, this approach created a lot of additional effort such as defining and documenting indicators corresponding to CIB descriptors and input time series corresponding to variants; model requirements were in conflict with qualitative scenario interests and policy simulations were asked to respect CIB scenario constraints even if *scenario* and *policy* were, from the modelers' view not separated in a sufficiently clear manner etc.

ple was then left to the CIB and to the CIB scenario experts. Especially in the Lima Water case, neither the members of the scenario group nor the modelers felt sufficiently integrated during this step. This resulted in limited ownership and therefore in the reappropriation of the scenario sample and some self-distancing from the CIB-based scenario sets—and at the same time from the CIB scenario experts' control of this sample.[412] On the other hand, CIB scenario-experts, and especially those with deep experience with CIB, were a new actor group within such a combined CIB&S scenario process, an actor group that certainly gained a powerful position in both case studies.

Overall, this phenomenon appears to be linked as much to the structuring effects of CIB as to the social organization. In the Lima Water case, the phenomenon was clearly influenced through the non-inclusion of modelers in the CIB and of the scenario group in the sampling. Comparably, in a full version of the UBA CIB&S application, the different model groups might need to be included in the CIB, too, to ensure the representation of their perspectives and modeling requirements.

Issues of effort, closure and creativity: using CIB in integrated scenario methodologies requires additional resources

In both cases there are hints that the use of CIB requires considerable effort and resources, especially when the CIB matrix is required to be flexible in the face of changes, and also when the intention is to provide room for scenario creativity. In both cases, the CIB was perceived as resource intense, especially in terms of time, effort, willingness and ability to open up to a new, uncomfortable way of thinking and to acquire new method capacities. Furthermore, in both cases the approach was not very flexible with regard to the uptake of new information, changing assumptions or changes in the scenario ideas as a whole. This is something that was anticipated and perceived by the participants in both the UBA and the Lima Water projects.[413] In the Lima Water case, the inflexibility of the CIB matrix may not have been due exclusively to the systematic character of the CIB alone or to a lack of ability to handle the method, but mainly due to the fact that its legitimacy was based on participation: All changes to the matrix would have required further consultation with the entire scenario

[412] Overall, in the Lima Water case there was an apparent tension between the attempts of both actor groups (modelers and the scenario-group) to (re-)appropriate the scenarios and to tailor them for their needs on the one hand and the consistency assurance in terms of CIB actively supported by the scenario experts on the other hand. This tension existed between methodological rigor on vs. local anchorage and ownership (with regard to the scenario-group) and vs. model and simulation requirements and needs (with regard to the modelers).

[413] Overall, in the UBA case*,* rather open questions were raised how a CIB&S methodology can ensure the flexibility and adaptability of framework sets over time.
In the Lima Water case, all loops during the construction of the CIB matrix have been perceived as requiring additional effort. Furthermore, the CIB matrix and in consequence, the CIB based scenario sample, have been resistant to changes at several instances of the process. Second, after the discussion of the combined scenario brochure in May 2013, when the new scenario C was decided for, it was also decided *not* to adapt the CIB matrix and in consequence the entire scenario sample, at both instances with the argumentation that this would require way too much effort and resources.

group, whose members were already rather tired from the long process. Especially in the UBA case, creativity was perceived as lacking—something that occurred less in the Lima Water case. I suppose that in the UBA case, this is not an effect of CIB alone but rather of the position of the numerical models and of the system representation by the CIB that was limited to pre-existing, numerical scenario content reflecting the range and content of currently used model input data. In the Lima Water case, the scenario scope was far more open. The qualitative character, especially of the storylines, provided more room for creativity.

8.1.2.4 The role of the form of combination ("F")

Initially, I had expected that the effects of the CIB within combined scenario methodologies would depend on the *form* in which CIB was combined with simulation models. My expectations with regard to the effects of the three different dimensions *system representations, positions* of CIB vs. models as well as of the *link* between the two, were rather vague; see expectation "F" E 12. The evidence of my two case studies makes refining and individualizing these expectations possible, and even allows me to regroup the dimensions that I consider central to distinguish between different forms of the combination of CIB with numerical modeling and simulation.

The type of system representation mainly impacts the type of scenarios

From the UBA and Lima Water case I have learned that the type of system representation of the CIB mainly impacts the character of the scenarios that are constructed. In the UBA case, almost entirely numerical and model context-related issues were covered by the CIB, resulting in numerical indicator-context scenarios (input-data sets). In the Lima Water case, the water management system of Lima was covered qualitatively by CIB, leading to raw qualitative system scenarios that were then further processed and integrated with the further scenario forms. The issue of overlap between system representations in turn seems to be more directly related to the issue of 'link', discussed below.

The positions mainly impact the influence of the CIB on scenario content

The UBA and Lima Water cases confirm the expectation that the position of the CIB influences the impact of the CIB on the scenario process and products. More precisely, the position largely determines whether the CIB influences mainly the (apparent) (input) scenario *structure,* while the *content* is rather defined by the numerical models (see the case UBA, models first), or whether CIB mainly influences the (apparent) scenario structure *and* content (cf. the case Lima Water, CIB first). When the CIB is developed before the models, it can prime the scenarios with regard to their content, too. When the model is given, it might predefine, and potentially limit, the scenario scope. A pre-developed CIB is free to go beyond this (model-related) scope.

The type of link seems to be important for traceability and consistency effects of CIB

The expectation that the closer the link of the CIB with the numerical simulation model, the stronger its effects on process and products has mainly been confirmed by the Lima Water case: The link that was established on the level of scenarios (output-input coupling and soft link within the integrated scenarios) had the effect of promoting the consistency between different forms of scenarios—albeit on the level of appearance only.[414] In addition, the tacit and unsystematic comparison and potential adaptation of underlying model structures opened kind of a window onto the LiWatool model—but no deeper effect on model structures was demonstratable.

The overlap and the inclusion of actors play a role in these effects, too: Integration

Still, the type of link did not affect scenario traceability and scenario consistency alone, but was also related to the social organization, namely to the *inclusion of actors*. In addition, the question of *overlap* between system representations (what is inside vs. outside, endogenous vs. exogenous) seems to play a role with regard to the question, too. Both are related to the question of the level on which traceability and consistency can be achieved—or not, namely on the level of scenarios and/ or of models. In sum, I propose to regroup the dimensions link between the CIB and the numerical model together with the issues of iteration, inclusion of actors and overlap into the new dimension 'integration'. Integration and position then can be jointly used to characterize different forms of integrated scenario methodologies using CIB. This proposal and further insights are presented in the next section.

8.2 General insights into effects of CIB in different forms of combined and integrated scenario methodologies

In this section, I condense into six insights, what I have learned from my study on the use of CIB within different combined scenario methodologies. These generalizing insights have the double aim of answering my research questions and providing orientation to those, who are designing their own integrated scenario methodologies using CIB. These insights generalize the empirical evidence and my reflection on the two cases. They were discussed, refined and validated during an expert workshop (see chapter 5). I first propose a typology for different forms of the use of CIB within integrated scenario methodologies, each form giving CIB a specific function (8.2.1). Second, I summarize the types of effects CIB can have on the traceability (8.2.2) and consistency (8.2.3) of scenarios in integrated scenario methodologies and what factors promote and hinder these. Third, I propose an analysis of the interplay of scenario traceability and consistency in scenario methodologies using CIB

[414] In the Lima Water case, iteration B supported apparent consistency between the narrative and numerical parts of all the integrated scenarios. The absence of a full iteration in the sense of SAS might have hindered full consistency between all scenario forms.

(8.2.4). Finally, I turn to other effects and summarize the ways, in which the use of CIB may change the checks and balances within integrated scenario methodologies (8.2.5); and what its use causes — and requires—in terms of effort, flexibility and creativity (8.2.6).

8.2.1 Different functions of CIB in different forms of combined and integrated scenario methodologies: a typology

From my case studies I conclude that, for the design of the form, in which CIB is combined with mathematical modeling and simulation within combined or integrated scenario methodologies, two dimensions are central: The relative positions of CIB and the models, and the degree of integration.

- *Position(s)* of CIB and of numerical models: What is available first? Which comes before the other? Which of the components is primarily responsible for the content and structure of the scenarios and which one is the principle *benchmark* in case of mutual adaptations (*dominance*)? The idea-typical variants are models first vs. CIB first.
- *Degree of integration* of CIB and numerical models: How do CIB and numerical models overlap in their system representations? How are they coupled? Is the link direct (hard) or indirect (soft), uni- or bidirectional, implicit or explicit, one-time or iterative? What actors are included in what process activities (inclusion)? How far are scenario experts, scenario group and modelers included in the CIB as well as in modeling and scenario simulation? Ideal-typical variants are low vs. high degree of integration.

Using these dimensions as the axes of a four-field matrix, results in four ideal-typical forms of combination, or ways, in which CIB can be used within combined scenario methodologies.[415] Table 40 shows that in each combined form, CIB fulfills a specific function within the scenario methodology.

Table 40: Functions of CIB in ideal-typical forms of combined scenario methodologies

		Integration (overlap, link, iteration, inclusion)	
		low	**high**
Position (timing, impact on scenario content and structure, benchmark for adaptations)	**Models first**	type 1 CIB proposes general *context* scenarios to a model or a model group in the form of a non-committal, additional **service.**	type 2 CIB as an integrated **analyst and provider** of tailored framework assumptions for a model or a model group.
	CIB first	type 3 CIB as a **steersman** of a qualitative scenario process; models provide additional numerical information.	type 4 CIB is jointly used by a scenario- and modeling team to build a joint conceptual model as **a base for integrated *system* scenarios.**

[415] *Ideal types* are understood as theoretical extremes, not as most desirable forms.

In designs of *type 1 (service),* one or more mathematical models are in the dominant position within the scenario process and integration with CIB is low. CIB has the function of an additional *service*, providing internally consistent background pictures of possible *context* futures, qualitative and/or quantitative, to which the (different) modeling groups can compare their input data sets (that is soft coupling only).

In designs of *type 2 (analyst and provider)*, the models are developed before the CIB and are dominant with regard to the scenario content, too, but the degree of integration between CIB and the numerical model is intensified: The CIB is used to analyze and bundle the numerical input data (indicators and time series) of client models, also by taking up their assumptions on relevant interrelations. CIB is used to add missing information, e. g. on qualitative context developments and on interrelations, and to structure the input data into internally consistent sets that are specifically tailored to the model (group).

In designs of *type 3 (steersman)*, the CIB is in the dominant position with regard to scenario structure and content of *system* scenarios, and integration with the numerical models is low: A full CIB is carried out to build qualitative pictures of possible futures by a scenario group. Numerical models provide additional numerical information that is integrated into scenario presentations, e. g. on the level of storylines.

In designs of *type 4 (base for integrated systems scenarios),* CIB is in the dominant position with regard to scenario structure and content; numerical models are either newly developed or open to adaptation; integration is high. CIB is used as a joint conceptual model of a modeling and scenario-building team. Through the inclusion of modelers in the CIB and CIB actors in the modeling, the comparison and reciprocal adaptation of model structures (conceptual CIB and numerical model) is supported, resulting in fully integrated narrative *and* numerical system scenarios.

The empirical UBA case can be situated between type 1 and 2, its hypothetical full application closer to type 2. The Lima Water case can be situated between type 3 and 4, though, due to its limited integration on the level of models, a little closer to type 3.

An important difference between model first and CIB first approaches is that in the former, CIB is used to construct model *context* scenarios that can contain – potentially exclusively – *numerical* definitions of future developments, whereas in the latter, CIB is used to construct more independent *system* scenarios, also or exclusively containing *qualitative* definitions of future developments.

This typology shows the extremes from very high integration that is required in type 2 and 4 to very low integration in types 1 and 3. My empirical experience suggests that this is a gradual dimension. Higher degrees of integration seem theoretically possible, but very challenging. To effectively using

CIB as a joint conceptual model (as required in both type 2 and 4), more practical testing and learning is required. Still, my findings suggest that in the project practice, teams might have good reason to opt for lower degrees of integration, too.[416] *Combined* rather than *integrated* approaches might still be beneficial to inter- and transdisciplinary research teams in supporting their scenario work. What difference the form makes with regard to the expected effects of CIB (e. g. on scenario traceability and consistency) is further summed up in the following.

8.2.2 Factors for effects of CIB on scenario traceability

The use of CIB can support scenario developpers to make scenarios resulting from integrated scenario processes more traceable. Most notably, CIB supports the traceability of assumptions on future (societal) developments in the raw CIB scenarios as well as in the derived narrative, numerical and integrated scenarios forms. But to ensure that assumptions on interrelations between future developments as well as the composition of individual scenarios and of scenario samples become and remain traceable, the following conditions need to be fulfilled for internal and external actors, and in the design types 1-4.

- *Understanding CIB:* Only one, who understands CIB quite well, can follow the assumptions on interrelations that are stored in the matrix and the composition of individual scenarios that is supported by the balance algorithm of CIB. If the understanding of CIB is incomplete, the traceability effect is restricted.
- *Keeping assumptions on interrelations explicit*: If the matrix and the underlying textual justifications on impact assessments are visible and accessible to someone, then this person can trace the assumptions on interrelations. This is not the case if the scenario table is primarily what is communicated, and if interrelations are not sufficiently represented within the storylines, which are limited through their length and linearity.
- *Documentation of sampling*: Only if the scenario sampling is openly documented, including sampling decisions beyond the CIB algorithm, it can become traceable to externals.

Finally, using CIB can have traceability effects for non-modelers on the numerical models and, in consequence on the numerical scenarios, if the model structures, e. g. simulation decisions as well as causal interrelations underlying model outputs, are revealed and compared. This effect is more likely in combinations with a high degree of *integration* (design types 2 and 4). The *position* of CIB does not seem to play a direct role for traceability effects.

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416 Integration is also a question of *resources*: What is possible? To what degree are non-modelers able or willing to dive into the mathematical modeling? To what degree are modelers ready to invest in understanding social context developments and/or the CIB?

8.2.3 Factors for effects of CIB on scenario consistency

If the CIB algorithm is used to compose individual scenarios, then internal consistency of these scenarios (according to the CIB consistency criterion) is ensured. If all scenarios of a chosen sample are based on the same CIB matrix, then there is also consistency within this sample. In integrated scenario processes, this consistency of the raw CIB scenarios can propagate to the narrative storylines and to the sets of numerical input data, and thus support the consistency between different forms of scenarios. However, this effect depends on different factors.

- *Support through CIB-generated data and CIB advocates can help*: The propagation of internal scenario consistency does not occur automatically, but can be actively supported by the use of CIB-generated data (e. g. scenario table, matrix, impact diagrams) as well as by the active work of CIB advocates, i.e. actors representing and following the CIB, e. g. during the writing of narrative storylines and during matching, i.e. during the translation into numerical scenarios.
- *A shared understanding of the system among* the different actors included in the processing of the raw CIB scenarios (as for example modelers, storyline authors, scenario group etc.) supports the consistency between different forms of scenarios. Otherwise, the propagation of scenario *structures* and *contents* is threatened by various types of distortion and bias (such as the subjective perspective of storyline authors, model needs and simulation requirements, which may not correspond to the assumptions of the CIB scenarios). These biases can be reduced, if taken on at an early stage, as follows.
    - All actors included in the construction of the different scenario forms are also included in the CIB analysis.[417]
    - Detailed and joint textual definitions of all scenario elements are produced and accessible, which go beyond short titles of descriptors and variants of the CIB and criteria (model outputs).
    - Numerical definitions of those descriptors and variants are agreed upon that are used to define model input.

The *degree* of consistency that can be reached between different scenario forms depends on the depth of model comparison and adaptation which in turn depends on the degree of *integration*. If storylines, input data sets and also model outputs are brought into line with the general ideas of the CIB scenarios, consistency on the level of appearance is reached (design types 1 and 3). Achieving

[417] In turn, engaging with the CIB requires a certain openness to interdisciplinary thinking and to the systems perceptions and representations of others. At the same time, it can support exactly this.

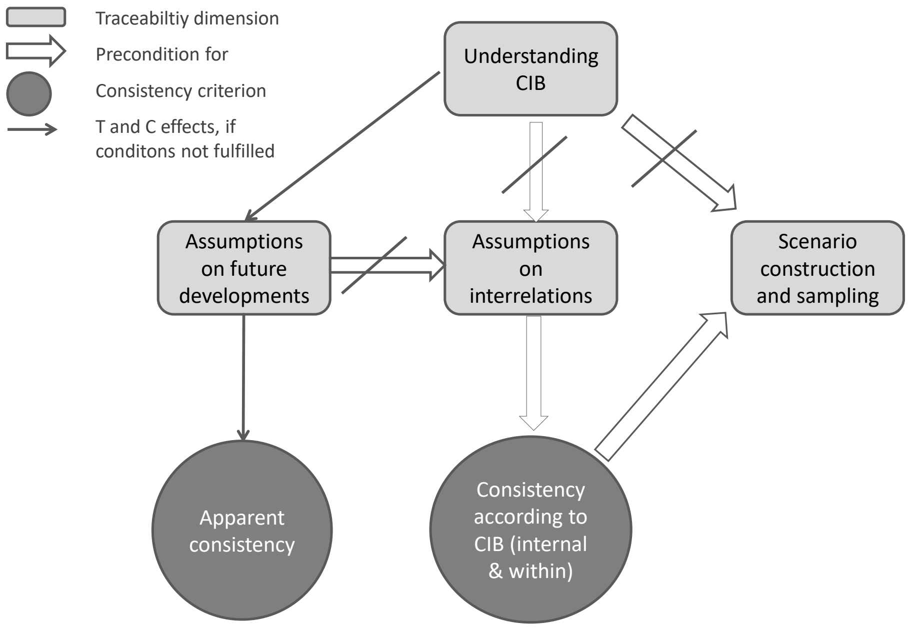
deeper degrees of consistency between CIB scenarios and numerical scenarios requires not only explicit and systematic model comparisons, but possibly also the mutual adaptation of the conceptual and numerical models (design types 2 and 4). Both in turn, ideally require the following practices.

- CIB should be used from the start for joint conceptual modeling by the modelers and the other scenario actors.
- Not only input assumptions and output criteria of the numerical models, but also internal model assumptions should be made available to the non-modelers dealing with the CIB.
- Coupling between CIB and numerical models should be made possible in both directions and iteration should include not only adaptations of storylines and input assumptions but also the mutual adaptation of internal model assumptions.

Thus, consistency effects depend more on the degree of *integration* than on the relative *position* of the CIB and the models.

8.2.4 Understanding CIB is a precondition for scenario traceability, which is a precondition for scenario consistency

Figure 25: The interplay between scenario traceability and consistency in integrated scenario methodologies using CIB



In integrated scenario methodologies using CIB, scenario traceability is a precondition for scenario-consistency: Understanding CIB and having access to assumptions on interrelations are both preconditions for understanding the application of the CIB consistency criterion. At the same time, understanding the application of the CIB consistency criterion is a precondition for the traceability effect of

CIB on the composition of individual scenarios and of the CIB-share in scenario sampling, see Figure 25. In sum, several questions remain, namely *who* (member of the scenario group, modelers or external users) needs to *trace what* and needs what *degree of consistency* in what situations? Are there differences between different design types, such as context and system scenarios?

8.2.5 CIB creates new checks-and balances[418] in combined scenario processes

CIB is used within integrated scenario methodologies to construct qualitative (context or system) scenarios and to support the selection of scenario samples. Thus, CIB takes over a task that, without it, was carried out through rather intuitive approaches either by the modelers themselves (modeling only) or through the scenario group (SAS). If CIB is used, neither the modelers nor the scenario group have a direct control over the scenario structures, but mainly the two tasks to contribute to the definition of selected elements of scenario content, namely of descriptors (and indicators) and variants (and time series); and to assess interrelations between possible future developments. The task of bundling these individual content elements into scenarios is handed over to the CIB and the definition of the scenario sample then falls to those actors with CIB expertise, i.e. often the CIB scenario experts.[419] Whether and under what conditions this new distribution of tasks between modelers and scenario groups is perceived as helpful (CIB as support) or restrictive (CIB as straightjacket), is an open question. The new checks and balances presumably depend directly on the *position* of the CIB within the combined scenario process. The acceptance to use CIB within integrated scenario methodologies and the ownership of scenarios developed with the help of CIB in turn presumably depend on whether and how actors are themselves (actively) included in the CIB analysis and in the scenario sampling (*social integration*).

8.2.6 Effort, flexibility and creativity of combined scenario processes using CIB

First, using CIB—independently of the chosen type of design and form of combination—requires a certain effort, especially because of the necessary appropriation of method expertise and the need for sufficient time for its application. A hurried or superficial application of CIB, to save some of this effort, can lead to biased results. Furthermore, due to the systematic character of CIB, at every feedback and learning loop that requires changes to the CIB matrix, one should check whether further changes of the matrix are required in response (e. g. the adaptation of impact assessments, the weighting of the strengths of impacts). Finally, every change to the matrix can induce a change in the

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418 This expression means *reciprocal power control and division of power*, originally referring to the political system of the USA.

419 The use of CIB does require a certain degree of expertise in the method. If this expertise is not given among the modelers (or the scenario group if there is one), a new actor group comes into play, namely the CIB scenario experts responsible for the CIB analysis.

scenario sample based on this matrix. If resources are scarce (especially pertaining to time and method expertise), it can happen that once a CIB matrix has been filled, it is not easy to change it again. In sum, flexibility can be a challenge. Second, CIB itself is not a creativity-inducing method in the classical sense of allowing the free generation of new ideas. On the contrary, CIB divides scenario spaces analytically into scenario factors and their variants as well as their pairwise relations that are characterized by simplified impact assessments. Depending on the kind of storylines that are aimed at, CIB may be useful to support, but not sufficient to help generate new ideas and imagery, nor to finalize the redaction of narrative storylines. Thus, CIB might need to be combined or complemented with further qualitative, normative, creative or even artistic approaches, see also section 8.4.

8.3 Discussion of the conceptual framework

In this section, the conceptual framework of the study is critically discussed. This framework structured the empirical analysis and has guided the study toward the answers to my research questions. It required being at the same time precise and specific as well as general enough to be applicable to two rather different cases. First, I summarize my experiences regarding the empirical usefulness of the framework and propose some adaptations and refinements (8.3.1). Second, I discuss how far elements of the framework are generalizable beyond this study and potentially also transferable to (combined) scenario methodologies in general (8.3.2). Third, I reflect on how this framework has influenced, meaning at the same time allowed and biased, the perspective and results of this study (8.3.3).

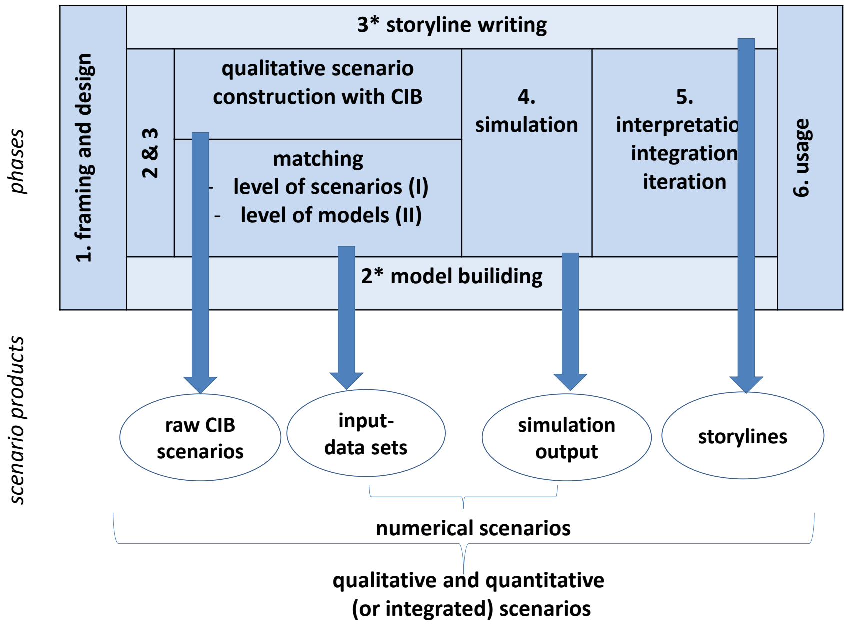
8.3.1 Empirical usefulness and refinement of individual conceptual elements

The conceptual framework, as presented in chapter 4, was not developed fully independently from but rather in parallel to the design of the empirical case studies. Its application to the empirical material during data analysis then allowed further learning effects. These are detailed in the following: Overall, the individual conceptual elements were rather useful for describing and analyzing the use and effects of CIB within the specific scenario methodologies in the two cases of UBA and Lima Water. Furthermore, the application pointed at several refinements.

8.3.1.1 A more CIB-specific process model

The initial CIB&S process scheme was useful for an initial structuring of the scenario processes of both cases into comparable phases and activities—even if the empirical process models of both cases diverged from it fairly significantly. Taking the experiences from both cases together, I would like to propose a refined process model, more specifically tailored to integrated scenario methodologies using *CIB*. Figure 26 shows such a refined process scheme. It gives up the consecutive character of phases 2 (CIB) and 3 (matching), which are now considered parallel activities in CIB&S methodologies.[420] Also, matching is explicitly split into matching on level I, the translation on the level of scenarios, and matching on level II, the comparison and adaptation of model structures. In addition, storyline writing and mathematical model building are added as separate, but closely linked activities that I propose to consider as optional features. If they are carried out, they should not be considered external to the process. Storyline writing was added as a scenario construction activity sui generis, as descriptions of raw CIB scenarios are not sufficient in all cases. Finally, I added *interpretation* and scenario *integration* to the iteration phase. Whether full iteration in the sense of SAS is a realistic and necessary feature of CIB&S methodologies is discussed below (section 8.4).

Figure 26: Refined CIB&S process scheme: simplified model and its resulting products



8.3.1.2 CIB&S methodologies and forms of the combination

First, I used the framework developed by Hinkel (2008) on transdisciplinary methodologies to describe and characterize the CIB&S methodologies of both cases. As I criticized above (chapter 4), the categories of the approach (activities, methods, actors, data, impact) remain rather broad and, in addition, weak from the point of view of social sciences. In addition, they are not completely distinct, since methods are always decided upon and applied by actors and since data is produced and processed by actors or methods, too. Nevertheless, the use of additional definitions and operationalizations, especially of methods, actors, data, activities and types of effects of CIB&S methodologies, made it possible to apply the framework to follow the scenario processes analytically

[420] It is considered an empirical question whether the matching is carried out first (e. g. in 'model first' designs) or whether it follows the CIB analysis (e. g. in 'CIB first' designs) or whether both are effectively carried out in parallel—and on what level matching occurs. All of these variants have their specific advantages and disadvantages and depend on the type of process (qualitative and open or numerically predefined), on the resources and on the type and function of the intended scenarios.

step by step (meaning over time and following their dynamics) and to characterize the overall social organization, technical design and cognitive or data-related dimension of the two idiosyncratic cases. The medium level of granularity chosen was appropriate for this study. Still, a much higher level of detail would have been necessary to systematically make visible all Iterations, detours, and repair activities.

Second, based on a review of the literature, I derived dimensions with which to characterize different forms, in which CIB can be combined with numerical simulation models. Regrouped into the three dimensions of system representations, positions and link, they supported rather static characterizations of each case. These dimensions provided a different and more synthetic and generalizing angle on the methodologies, focusing on the CIB method and the numerical models. Even if these were not entirely distinct either—for instance, system representations and positions seem to be interlinked. – they were distinct enough for the aims of this study.

Nevertheless, there is some overlap between these dimensions and the concepts proposed by Hinkel. Each form of combination is embedded in and realized through a particular form of social, technical and cognitive or data-related organization. This led to doublings during coding and to repetitions in the case characterizations. Finally, in the overall typology on forms of CIB&S methodologies, I have condensed both approaches within the dimension of integration, including the social organization as a feature of the form of combination. Accordingly, the position of CIB relative to the numerical models is interrelated with the position, standing, charisma and resources of the actors, and the institutions and organizations working with these methods. From the evidence of this study, it is still not perfectly clear how the characteristics of the methodology (in their dynamics) and the final form of combination (rather static) are shaped by and shape each other. In sum, the analytical division between and the integration of both angles might need further conceptual considerations to come to an even clearer and more economic framework.

8.3.1.3 Assessing outcomes: Scenario traceability and consistency

Overall, the working definitions and sub-dimensions of scenario traceability as well as of scenario consistency were suitable for assessing the outcomes of both methodologies. The four dimensions of scenario traceability were helpful, when it came to showing on what level traceability effects did or did not occur. With regard to the different levels of scenario consistency, it was especially fruitful to distinguish between consistency on the level of scenarios and on the level of underlying models. Nevertheless, there were certain difficulties.

Both concepts were analytical ones and did not play much of a role for the participants of the case studies themselves. This holds for the majority of the interviewees, namely those, who were not CIB scenario experts but modelers or members of a scenario group. This issue points at the question of the degree to which scenario traceability and consistency are relevant categories for the actors of the integrated scenario processes at all, and in how far, for them, scenario quality depends on other aspects that have not been considered in this study (see mainly section 8.4.3).

Also, the application of the framework during the analysis revealed that some of the dimensions of the working definitions need further refinements. Especially the first dimension, the traceability of assumptions on future developments, is a broad one that does not sufficiently distinguish between *what* is assumed and *why* it is assumed, that is to say what justifications and reasons may be given for the assumptions behind the assumptions. Similarly, when it is indicated that scenarios have been constructed with CIB—and their construction is then a priori traceable on the surface—a deeper understanding requires more insight into justifications. This brings back the two different intensities of traceability already introduced above, namely tracing something vs. understanding something. These intensities of traceability should be taken up in further research. Finally, open questions remain with regard to the issue of what needs to be traceable and/or understandable by whom. To more specifically analyze these dimensions, different types of (internal and especially external) users and their requirements need to be conceptually and empirically analyzed in more depth than it has been possible in this study.

With regard to consistency, consistency with current knowledge had been explicitly excluded from the consistency levels. Nevertheless, empirically, this level played a considerable role for scenario users and producers. In both, the UBA and Lima Water case, they were important to justify the definitions of descriptors and indicators and the selection of variants and especially numerical time series. The justification of these, using then-current knowledge, seemed to constitute a good part of their acceptability. Therefore, in further studies, this level might need to be included in the analysis. Furthermore, as consistency between scenario forms was analyzed on the level of *appearance* only (in the Lima Water case), additional and more detailed categories to compare verbal and numerical (input related) scenario forms were developed during the analysis, namely apparent scenario structure (in contrast to the underlying model structures) and the scenario content. Scenario content was further characterized by the type of representation (qualitative vs. quantitative shares), the type of coverage of the translation (fully or partial, split into more than one indicator) as well as the direction and spread of variants and time series.

In sum, the difficulties encountered during the empirical application, show perspectives on how to further refine the quality criteria of scenario traceability and consistency in future research.

8.3.1.4 Interpreting effects

Overall, the chosen approach to describe methodologies, to assess their outcomes and then to interpret, how effects were caused by the different elements of the methodologies and their interplay, was applicable and fruitful.[421] Both empirical case analyses have shown that it was indeed possible to stretch the framework developed by Hinkel (2008) from a descriptive to a more analytical one. But the search for the patterns of effects was mainly based on interpretational work that is of course subject to alternative interpretations and critique. Overall, the first-order effects of the nomothetic core of CIB were quite easily to identify. It was way more complex to disentangle second- and even third-order effects, which CIB was clearly not causing alone, but together, with, or against other elements of the methodology. This methodology was both shaping and shaped by the specific design of the CIB and its form of its combination in the individual cases. In consequence, it required another interpretative layer to generalize effects and to identify their patterns.

8.3.2 Transferability

The conceptual framework was developed to analyze the specific empirical cases of this study. And the final typology of forms and functions of CIB in integrated scenario methodologies is indeed somewhat colored by the empirical examples underlying it. Nevertheless, I consider that the conceptual elements are broad enough to be applicable and useful to the analysis and for the design of further cases of integrated scenario methodologies using CIB. Especially the process scheme in its refined form is now specifically focused on *CIB*&S processes. Other elements even seem to be transferable to scenario methodologies beyond the CIB&S type: The dimensions to characterize forms of the combination seem applicable to various types of combined and integrated scenario methodologies—and are not necessarily limited to those using CIB. The working definitions of scenario traceability and scenario consistency are applicable to assess outcomes of all forms of scenario methodologies, integrated ones and others. Nevertheless, transferability is assumed and still needs to be empirically tested.

8.3.3 Beyond the frame(work)

> Six blind elephants were discussing what men were like. After arguing they decided to find one and determine what it was like by direct experience. The first blind elephant felt the man and declared, “Men are flat.” After the other blind elephants felt the man, they agreed.
>
> (Elephant joke, anonymous, ca. 1960)

Considering the *exploratory* character of this study, the conceptual framework, developed in important parts a priori, was fairly comprehensive and strongly pre-structuring. This choice was made to clearly guide and to focus the study. This was necessary in order to cope with the complexity and multidimensionality of the phenomena visible in two strongly diverging cases, and to deal with the huge amounts of empirical data. And indeed, the rather detailed and explicit framework worked to

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[421] The framework borrowed from Hinkel (2008) from the field of transdisciplinary assessments has proven its usefulness beyond its initial focus.

focus the study on my research questions, to develop explicit expectations and pre-structure the data collection and the data analysis of the two rather different case studies. I assume that my choice of framework had structuring effects, not only on data collection and analysis, but also on the results. It may have had unintended effects of blindness, or deafness, and bias, as well.

First, the focus on combined scenario approaches *of the SAS-type* introduced bias into this study. It risked neglecting further potentially possible forms of the use of CIB within combined scenario methodologies, such as the use of CIB *in addition* to more intuitive approaches, as well as the parallel and equal use of CIB and simulation, without one component being an input for the other, for example. Also, it risked taking over the implicit (epistemological) assumptions of SAS, most notably the apparent positivist tendencies of the approach (for further discussions of these points see sections 8.4.2.4 and 8.4.3.2).

Second, for the benefit of allowing some comparison between the two diverging cases, the framework was rather restrictive and limited openness with regard to each individual case and the idiosyncratic learning effects of the use of CIB in the individual cases. Third, the framework strongly predefined the particular focus on scenario traceability and consistency. The category of other effects had been introduced as an exploratory countermeasure. But to what degree this effectively allowed the revelation of central phenomena remains unclear.

Overall, the results are framed through my basic assumptions and conceptual elements, which in turn are also influenced by those frames, which I did not select consciously, namely from my perspective as a social scientist, trained as a qualitative and participatory scenario developer, and ultimately, as a colleague of those who have developed and advanced CIB.[422] Someone else, steeped in sustainability research or mathematical modeling, may very well have set up a different conceptual framework. Therefore, it is especially interesting to contrast my findings with those of others who, from the context of their own disciplinary and conceptual background, attempted to answer the question of whether and how CIB supports transdisciplinary project teams in constructing integrated scenarios of socio-environmental systems.

In the next section, the results of this study are confronted with the state of research. My findings are discussed with the experiences of others with CIB; with the field of combined scenarios, also by going beyond the dominant SAS perspective; and finally, in the light of current developments in futures research.

[422] For my roles and bias, see also chapter 5.

8.4 Results in the light of the state of research

In this final section, I discuss the findings of this exploratory study in the light of the state of research.[423] In addition, I contrast the findings with selected very recent work that was published in parallel to this study, but after the completion of the empirical case studies in March 2013. This literature had not yet influenced the development of my conceptual framework or expectations. First, I discuss empirical findings with respect to the state of CIB method research (8.4.1). Second, I confront my findings on CIB&S with the state of research on combined scenario methodologies, considering SAS-type approaches as well as methodologies beyond that framework. (8.4.2). Third, I define the precise place of CIB&S in futures studies (8.4.3). In sum, I argue that using CIB within integrated scenario methodologies is a new approach for supporting the more academic side of environmental studies and futures research.

8.4.1 Considering CIB method research

In the following, the results of this study are contrasted with the state of research on CIB. I start with insights on the users' perception of CIB, discuss different design options and elaborate on the relationship between CIB scenarios and storylines

8.4.1.1 The users' perception of CIB

This study set out to explore CIB in a specific form of application, namely within integrated scenario methodologies. At the same time, it was the first empirical study that not only used, but systematically reflected on the effects of CIB, and on how CIB is perceived by its users. Its findings match some of the effects of CIB that had been postulated by CIB authors (e. g. Weimer-Jehle 2006, 2009, Lloyd/ Schweizer 2013) and that are empirically hinted at in the broad range of CIB projects. These concern, among other things, the effectiveness of CIB as a tool for interdisciplinary group modeling among experts. But, some claims need to be differentiated. For instance, CIB authors claim that the method is, in opposition to other forms of systems analysis and in opposition to other systematic-formalized scenario approaches, easier to understand because it has a consistency logic that is traceable by using pen and paper (e. g. Weimer-Jehle 2006, 2009). In contrast, both cases indicate that a full – instead of a vague – understanding of CIB is not trivial to achieve, but requires preparation and skillful facilitation.[424] My findings also match an observation made by Wachsmuth (2014), namely that CIB

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[423] See chapters 2 and 3. For the central research gaps initially identified, see chapters 2.5 and 3.5.

[424] One could object that, in both cases studied, CIB was applied under especially difficult conditions, since in the UBA case the process was very short, not leaving much room for learning among the scenario-group; and in the Lima Water case, it was not academic experts who participated (as classically in CIB) but local stakeholders, who found the understanding and use of CIB challenging. But, in both very different situa-

matrices risk becoming outdated quite quickly. The Lima Water case showed that at the end of a long (!) CIB process, the system—or at least its perception by the stakeholders—had changed, but no resources remained, with which to adapt the joint matrix (the conceptual model).

8.4.1.2 Designing CIB processes

CIB, and especially the cross-impact assessment phase, can be designed in various ways. Regarding the collection of impact assessments, in the literature there are authors, who prefer individual surveys to help prevent group effects (cf. Schweizer/ O'Neil l 2014), and others, who instead use CIB in group designs to benefit from the communicative validation and discursive quality of group situations (Weimer-Jehle 2010a: 7 ff., 2014: 255 ff.). My case studies showed that in the UBA case, the only weakly facilitated individual expert survey was prone to errors and bias. It required later facilitation and group discussion to correct those errors and bias, and to achieve better uncovering of underlying mental models. In the Lima Water case, the group process was perceived as very beneficial by the participating actors, but also had a closing effect on the matrix: Once the matrix was ready, all potential changes proposed by actors from outside the scenario group had to be pondered against the group legitimacy of the matrix. It would have required a lot of effort to check and reopen the discussion of the matrix with the whole group. In sum, the findings of this study suggest that both variants of CIB design (individual and group) have their respective advantages and disadvantages.

Furthermore, my findings match the recommendation by Weimer-Jehle (2014b: 2) that the standardization convention protects against positive bias—and leaving it out (as in the UBA case) means accepting this bias. At the same time, leaving standardization out might, to a certain degree ease the straightjacket nature of the cross-impact assessment procedures for the users (cf. the Lima Water case). In addition, current literature on CIB seems to underestimate the impacts and importance of scenario method expertise and of CIB scenario experts on scenario processes and results, especially during CIB analysis and sampling.

8.4.1.3 CIB and storylines

Contrary to the expectation that a CIB can be used to construct storylines, which is implicit especially in early CIB publications, this study indicates that CIB and the new features of ScenarioWizard, such as the scenario table, protocol and automated impact diagrams, can in fact be used to *prepare* or *complement* storyline writing. This seems especially useful, when these texts either represent (model) context developments or—but this application is still theoretical—internally consistent bundles of policies. But depending on the intended type of narratives or storylines, CIB might not be sufficient to

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tions, members of both scenario-groups had almost identical difficulties understanding and correctly applying CIB.

write storylines. Depending on the aim of the scenario process, and especially when communicative and normative functions are central, it might be necessary to also integrate creative counterweights. These could represent the scenario space through more holistic perspectives, discontinuous developments (e. g. Van Notten 2013), tensions (e. g. Erdmann/ Schirrmeister 2016), nuance and detail, e. g. with regard to actors, institutions, their decisions and effects of these (e. g. Hughes 2013). One might also consider combining CIB with holistic and explicitly normative visions to complement their perspectives. For this line of thought, compare the work by Stauffacher, Muggli and Moser (forthcoming), who have combined normative visions *and* systematic scenarios with FSA. Such a combination of CIB and visions would form an entirely *qualitative* type of combined scenario methodology. This type of qualitative combined approach then requires the translation of holistic visions into explicit and distinct scenario factors as well as the interpretation of scenario factor bundles as visions.

8.4 2 A new type of combined scenario methodology

In this study, CIB was explored within new forms of combined scenario methodologies, and more specifically in combination with mathematical modeling and simulation, with the aim of supporting the construction of integrated scenarios of socio-environmental systems. This study provides the first systematic conceptual and empirical findings on forms of CIB&S. Comparing these with the state of research on combined scenario methodologies, especially of the SAS-type, shows that CIB&S proposes some new and promising approaches to specific challenges of SAS, but remains itself challenged by some of the fundamental issues concerning combined and integrated scenario methodologies in general (8.4.2.1- 8.4.2.3). Furthermore, this study makes one step towards developing new forms of combined and integrated scenario methodologies going beyond the dominant SAS-type approach. From here, further steps could be undertaken (8.4.2.4).

8.4.2.1 Tackling the traceability challenges

Overall, this study suggests that combined scenario methodologies using CIB offer some new answers to the traceability challenges confronting SAS-type approaches—but that some issues remain.

First, using *CIB* within the combined methodologies of two distinct cases had the effect of supporting scenario traceability, especially with regard to *assumptions on future developments*: The qualitative scenario part is not based on the inaccessible mental models of its producers only (cf. Alcamo 2008: 142 ff.), but on the conceptual CIB model that makes these models explicit. This conceptual model provides access—at least for internals and for those with expertise in the method—to assumptions on future developments and on also on interrelations between those assumptions. In principle, the mathematical model has a qualitative model partner that it can be explicitly —though qualitatively— compared with on the level of system elements and interrelations. Nevertheless, for externals and non-method experts, *assumptions on interrelations* were covered again in the derived scenario forms

(e. g. the storylines and both parts of the numerical scenarios). Thus, the traceability challenge in CIB&S methodologies is transferred to the level of underlying models.[425]

Second, by using CIB instead of other intuitive approaches to scenario selection (through intuitive logics or through the modelers themselves), the task of composing *individual scenarios* is taken away from the—intuitive approaches of—modelers or scenario groups but is handed over to the CIB analysis and its balance algorithm. Therefore, it is traceable—at least for those, who understand the method. This is clearly an improvement on current standard practice, as for example the UBA case indicates.[426]

Third, the traceability of the scenario *sample* and of the *assumptions on interrelations* also depends on the participants having access to the documentation. As in Parson (2008), this study was based on the assumption that scenario traceability could be a substitute for participation. Still, in both cases, there were difficulties realizing traceability even for those project internals (e. g. the modelers), who were in the role of externals with regard to parts of the CIB. The findings suggest that achieving an appropriate substitute seems very demanding in terms of documentation, expertise in the method and explication. Perhaps the hope for full substitutes should be more realistically lowered to good enough substitutes, which might allow externals to trace a process but, in practice, will never fully substitute for participation. A first proposal for what might be (reciprocal) information requirements in CIB&S was given in 8.2.2.

Furthermore, the experiences with my case studies mirror the diagnosis by Parson (2008: 4), that even if traceability is widely advocated, it is seldom achieved as it requires "embarrassing" (ibid.) uncovering of errors, detours and pragmatic decisions. For instance, in the Lima Water case, being explicit with regard to numerical model inputs across scenarios was perceived as desirable in principle, but actors from the core team, scenario experts as well as modelers, also feared external critique of their assumptions, as some of them were ad hoc assumptions.

Kemp-Benedict (2004: 2) with reference to SAS type methodologies, had formulated the hope that the combination of qualitative storylines with simulation models could increase the traceability of both components. Considering the traceability challenges that mathematical models have, at least

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[425] Whether and how CIB&S empirically can achieve further traceability effects on numerical modeling itself (see the window effect in the Lima Water case), seems to strongly depend on the social and technical organization of matching, see 8.4.2.3.

[426] This applies to the practice of 'modeling only' as well as to classical SAS approaches (cf. also interview UBA expert A (18)*: "My problem with the Story and Simulation method is–and that is comparable to issues of scenario planning, but the latter has this problem to a lower degree – that it is incredibly difficult to trace, how one ended up with the story […] „From what I know, this [selection of key factors] is not very transparent, difficult to document and very often serving the needs of the model. That means, that the factors are oriented and determined by the model and this, of course, results in a very limited picture of the future."*

for non-modelers, one could question this hope, and expect that bringing two components with traceability problems together might in fact increase the non-traceability of the entire approach. The evidence, especially from the Lima Water case, supports both positions. On the one hand, the combined CIB&S approach is more complex than isolated qualitative or model-based scenarios are, and the matching (level I) is a source of further non-traceability. On the other hand, the simulation of the CIB scenarios was successful in opening a window on the overall aims and functioning of LiWatool for the non-modelers of the project. In sum, this hope could be justified in CIB&S methodologies, if adequate forms of matching are carried out. In the following section the issue of matching will be further discussed with regard to consistency issues as well.

8.4.2.2 Reversing the promise of consistency

Overall, the findings suggest that in CIB&S methodologies, the promise of consistency might be reversed. In both methodologies, unlike in SAS, the burden to ensure scenario consistency—of the qualitative scenarios, first of all—is handed over to the CIB. Findings suggest that the *internal consistency* of the qualitative CIB scenarios is easy enough to ensure, namely through the correct application of CIB. If all scenarios of a chosen sample are based on the same CIB matrix, then additionally, consistency *within this sample* is given, too. The UBA case shows that this is also perceived as an improvement on modeling only approaches.[427]

As the Lima Water case shows, the consistency of the raw CIB scenarios can—but does not automatically—propagate to the narrative storylines and to the sets of numerical input data, and thus supports the consistency *between* different forms of scenarios. In the Lima Water case, consistency between different forms of scenarios was achieved on the level of appearance only, meaning that input data sets and model outputs were in line with the general ideas of the CIB scenarios and the derived storylines.

Achieving consistency of *underlying models* is a more ambitious and demanding endeavor, requiring a high degree of integration between CIB and the mathematical models—that perhaps is neither

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[427] For instance, expert E stresses that he has learned a method to get *plausible sets* of framework assumptions in a *structured way*. UBA expert E (83): *"For me, the most important result is that I got to know a method that leads in a structured way to a plausible set of framework assumptions. This is the central result of this project for me."* Expert B (B 32-34) states that it is useful to have a *more scientific* procedure of choosing input parameters, in contrast to the typical modeling practice (see above) that she judges as not very scientific, but interest driven, where sometimes inputs are negotiated with regard to the results they produce (B 34) without considering whether they fit with each other. The need to improve the current practice is named as the special motivation for the UBA project (A 24): *"This is what motivated this project. This centrally is about the consistency, the plausibility and the interrelation of factors. The exogenous ones are certainly also coupled somehow, and not alone. Therefore, one should indeed dare to go one step further towards complexity—and not only deal with the mono-dimensional aspects, namely the individual framework data or assumptions."* And this has worked out well with CIB (cf. interview UBA expert A 99).

always possible nor necessary (as in CIB&S types 1 and 3, e. g.). In CIB&S methodologies, the former consistency check by the model is transformed into a process of comparing different systems representations (for the organization of matching on level II; see also 8.4.2.3 below). However, whether the responsibility for scenario consistency is fully transferred to the CIB, might depend on the type of model and modeling it is combined with. In my view, the reversion applies especially in those cases of CIB&S, in which the overlap of the mathematical model with the CIB is not important enough to allow comprehensive consistency checks of the (qualitative) CIB model through the mathematical model.[428] This estimation echoes the argument made by Schweizer and Kriegler (2012) and Kemp-Benedict (2012) explaining the limits to the promise of consistency in SAS.

In sum, scenario consistency is dealt with differently in CIB&S from the way it is dealt with in SAS. Still, based on the evidence of this study, I cannot judge whether in CIB&S approaches, higher degrees of consistency are automatically reached between narrative and numerical scenarios than in SAS. Therefore, real-world method comparisons, e. g. in the form of experiments, would be necessary. What I can say is that in SAS using IL, full iteration seems to be an important prerequisite for this purpose. With regard to CIB&S, it is an open question whether *iteration* needs to play a comparably important role; or whether the matching (level I and level II) could instead provide arenas in which to analyze and support consistency between different scenario forms and their underlying system representations.

8.4.2.3 The social, technical and cognitive organization of integrated scenario methodologies

This study indicates that the *social* organization of combined—and even more so of *integrated*—scenario methodologies is highly important for their successful application, but that just this social organization can be very complex and challenging. Within the SAS literature, there was not much guidance, on how to establish cooperation between actors as different as mathematical modelers and scenario group members (cf. Kemp-Benedict 2012). There is agreement in the literature that this is a “methodological challenge” (e. g. Van Notten et al. 2003: 431) and that this cooperation also requires taking into consideration that they may have fundamentally diverging epistemological perspectives. Based on this study, I clearly confirm this diagnosis. I would like to add, though, that it seems possible to deal with these challenges in various—either more pragmatic or more sophisticated—ways.

Clearly, this kind of cooperation requires reciprocal trust, openness and respect as Volkery and colleagues (2008) wrote. Otherwise, unclear responsibilities, misunderstandings, confrontation, and

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428 And if a system could be fully represented in mathematical form by endogenizing most scenario drivers, one would perhaps not choose to construct an additional CIB.

issues of ownership occur, as especially the Lima Water case indicates. In sum, the findings of this study mirrored the questions of power that were hinted at in the paper by Volkery and colleagues entitled “your vision or my model” (2009). Still, in CIB&S methodologies, I consider that checks and balances are slightly different from those in SAS through the introduction of a third power, the CIB, and—if CIB is not carried out by scenario groups or modelers alone—the scenario experts. Alcamo (2008) proposed for SAS to establish a scenario team that has an overview of the interfaces and sufficient understanding of possibilities and requirements of both components. From our experiences, especially in the Lima Water case, such a team at the interface would be ideally composed by modelers, scenario experts and if possible also representatives of the scenario group. As to the necessary resources, authors agreed that combined scenario approaches of the SAS-type are resource-intense. I consider that combined scenario methodologies using CIB are even more resource-intense, since they also require CIB method expertise and considerable time to carefully carry out the CIB.

The SAS literature proposes several formalized approaches to the translation of qualitative into numerical statements (Alcamo 2008, Kemp-Benedict 2010, Kok et al. 2015). The findings on CIB&S processes suggest that the difficulties of socially, cognitively and technically matching qualitative CIB and numerical models go far beyond those, which could be (easily) solved by the application formalized translation techniques. Instead, such matching ideally would require new social, technical and cognitive forms of *matching* on the level of scenarios (level I) and on the level of underlying model structures (level II). To go beyond the muddling through-type of matching activities, as in the Lima Water case, further conceptual thinking and especially practical learning is required.[429]

8.4.2.4 New forms of combined scenario methodologies

This study has contributed to developing CIB&S as a new combined or integrated scenario approach that can be designed in different forms. Furthermore, informed by this study, I propose a first glimpse at further new forms of combined and integrated scenario approaches, going beyond the dominant SAS-type—and also leaving the focus on those combining CIB for a moment.

CIB&S as a new combined scenario methodology—with a variety of forms

This study has shown that using more systematic forms of qualitative scenario methods for the qualitative side of SAS-type approaches is indeed possible and also beneficial. This confirms the expectations of several authors (as for instance Girod et al. 2009, Rounsevell/ Metzger 2010). Furthermore, CIB indeed seems to be an appropriate method to take over this part, as yet other authors had proposed (e. g. Schweizer/ Kriegler 2012, Kemp-Benedict 2012, Weimer-Jehle/ Prehofer/ Vögele 2013).

[429] Recently, Prehofer and colleagues (forthcoming) have analyzed the issue of knowledge integration in scenario methodologies combining CIB and energy models. They show that the use of CIB both requires and supports knowledge integration on different levels. My findings confirm their diagnosis.

Based on conceptually and empirical work, this study has shown that CIB&S methodologies, which are more structured and more systematic than SAS-type methodologies, can be considered to be stronger with regard to issues of scenario traceability and consistency. Thus, with CIB&S, the field of combined methodologies gains a promising new approach combining qualitative systems analysis CIB and simulation.

The review of literature on combined scenario methodologies showed a high empirical diversity of designs, but provided only very little conceptualization, reflection or guidance with regard to different combined forms. One exception was Kemp-Benedict (2004), who stated that the combination is beneficial only if the narrative leads. The findings of this study on CIB&S paint a more differentiated picture: Indeed, the functions of the combined CIB&S approaches are influenced by the position of the CIB. But also models first- combinations can be useful and beneficial, though with different aims (such as type 1 and 3). Furthermore, it is not the relative position of models and qualitative scenarios alone that plays a role, but also their degree of integration. The typology built with the help of these two dimensions has shown that CIB&S is not a monolithic approach, but that various combined forms are possible and that the effects of CIB&S depend on the specific form of the combination.

This typology also allows one to characterize the most recent designs of CIB&S that have been implemented in the field of energy scenarios (cf. e. g. Weimer-Jehle et al. 2016, Prehofer et al., forthcoming). The application by Weimer-Jehle and colleagues demonstrates the differences in model results, when these are based on intuitive data-input sets vs. on internally consistent CIB-derived context scenarios.[430] Prehofer and colleagues compare three different (ongoing) scenario building designs linking CIB with energy models.[431] They conclude that the use of CIB can fulfill different functions within different designs of integrated scenario methodologies. They state that the “timing of process steps, the degree of ‘coupling’, and the inclusion of actors” (ibid: 1) are central design dimensions. The empirical analysis of these ongoing CIB&S cases from the field of energy scenarios thus makes a fairly good match with the results of my study in the field of environmental scenarios.

Organizing qualitative and quantitative components in scenario methodologies

The experiences of this study with different *forms* of CIB&S can be used to discuss possible forms of combined scenario approaches more generally, namely going beyond SAS-type approaches and going

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430 This corresponds to a CIB&S application of type 2.

431 These three cases from the ENERGY TRANS project named A1-A3 correspond to the following CIB&S types: A1: type 1, with a few elements of integration; A2: between type 2 and 4; and A3 started as a type 3 but finally rather is a type 1 approach. These empirical types are all situated between the ideal types but can be characterized by using these.

beyond those using CIB. This allows catching a glimpse on the central varieties in organizing the relation of qualitative and quantitative (model-based) components in scenario methodologies.[432]

Dominance vs. equality

One central task for actors, who design forms of combined scenario methodologies, is to balance issues of dominance vs. equality of qualitative and quantitative components. In the SAS framework, models and qualitative scenarios are in a relation of dominance, either prolonging the dominant role of models from the initial modeling only approaches; or, by reversing the situation through defining the storylines as the master, the model as the slave. Trutnevyte and colleagues (2011, 2012) on the other hand had suggested that one should instead strive for an equal position and parallel development of qualitative and model-based components. Informed by the experiences of this study, I would like to argue that this choice might affect, whether a combined approach indeed fully benefits from the advantages that the two components have individually, that is when conceived as independent (equality); or whether the logic of one of the components primes the character of the overall process and its resulting scenarios (dominance).

Integration vs. combination

Another central task is to decide about the type and degree of integration – or non-integration – of the two components. In the SAS framework, integration through hard links (output-input coupling and iteration) is promoted. On the contrary, again drawing from the proposal by Trutnevyte and colleagues (2011, 2012), qualitative and quantitative components do not necessarily need to strive for maximum integration. Instead, they can also be conceived as rather complementary combinations. In such forms, qualitative and quantitative scenario forms and their underlying models do not strive to be fully translated into one another (integration). On the contrary, the benefit of the combination consists in the comparison, revelation and maintenance of their differences (combination). Complementary components might be especially useful, when both components have diverging functions, such as normative vs. exploratory ones. Integration might be more adequate, when both components have similar functions, such as in the combination of normative visions with optimization models, or in the combination of exploratory qualitative scenarios with exploratory simulation. Still, in the cases of integration and of combination, it is an open question, how best to support the necessary social, technical and cognitive processes of revealing, comparing—and only in cases of integration—adapting assumptions on future developments and on their interrelations.

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[432] To orient this discussion, which is turned towards the entire fuzzy field of combined scenario approaches, it might be useful to reconsider the three central, highly optimistic, arguments that are formulated in the SAS literature (see section 2.3.2.2).

In sum, this glimpse reveals that further research is required to fully understand, how to organize the relation of the qualitative and the quantitative in hybrid scenario methodologies. With this in mind, it might be useful to reconsider in more depth the efforts already made in systems thinking (e. g. Checkland 2000) and in the social sciences for "bridging the qualitative-quantitative divide" (Tarrow 1995).

8.4.3 CIB&S—an approach for futures research

First, I embed the quality criteria developed in this study in the latest discussions on academic criteria for futures research. Second, I reflect on the potential positivist undertone of CIB&S. To conclude the discussion, I define the specific scope of application of CIB&S.

8.4.3.1 The relevance of scenario traceability and consistency in applied futures research[433]

In parallel to this study, futures research communities have intensified their discussions about quality criteria and standards. How can one situate the criteria developed in this study within the current debate?

Traceability (*Nachvollziehbarkeit*) is demanded by Schüll and Gerhold (2015) as a general feature of good academic practice that should be required in futures research, too. They define measures to reach traceability very broadly from the precise definition of the research question, over the different phases of a study, to the tension between necessary documentation and the need to focus the documentation on the most relevant issues. Kuuri, Cuhls and Steinmüller (2015) propose a list of six "external validity criteria" of "futures maps," the last two of which are very close to traceability, namely those asking whether many people and/ or whether the relevant experts understand a futures map. The working definition of scenario *traceability* developed by this study is more specific, as it refers specifically to *scenario* methodologies and not to futures studies in general. Nevertheless, I consider that the three proposals could benefit from each other by establishing, how the validity *aims* required by Kuuri, Cuhls and Steinmüller could be reached by the traceability *means* proposed by Schüll and Gerhold, and what relevance they have for the four dimensions of *scenario* traceability defined in this study and for different scenario users.

Consistency is not included in the overarching criteria within either proposal. Still, under the heading of "argumentative testability" (*argumentative Prüfbarkeit*), Grunwald (2015: 43 ff.) proposes to apply the principle of consistency together with those of internal and external coherence as well as three different types of transparency. Thus, Grunwald's proposal emphasizes the links between traceability

[433] This section draws on Kosow (2015).

and consistency that have also been identified within this study; see 8.2.4. Again, the criterion of consistency as defined in this study is more specifically related to *scenario* methodologies, not to futures studies in general. I recommend that the notion of "coherence" as introduced by Grunwald, could be further discussed and operationalized with regard to CIB, too.

This reconsideration of the state of research emphasizes again that the criteria developed within this study clearly fall onto the *academic* side of scenario construction. As combined scenario methodologies, especially of the SAS-type, have academic ambitions, too (see 8.4.3.2), academic quality criteria are considered adequate to assess the quality of this type of scenarios (cf. also O'Mahony 2014: 46). They play a role with respect to their academic credibility, usefulness and acceptability. Nevertheless, combined scenario methodologies are also intended and expected to support policy advice and decision making—and the two criteria proposed in this study do not explicitly consider the practical perspective of the usability and credibility of integrated scenarios beyond science and research. Thus, scenario traceability and scenario consistency seem to be necessary conditions to assess the quality of hybrid scenarios, when these are used by experts in applied futures research for developing socio-environmental futures. In addition, the criteria also could be helpful to reflective scenario developers to guide them during their own scenario development and reporting activities. At the same time, the criteria are there to support external users or evaluators in their assessment of the scenario processes and scenarios produced by others, and in their decisions on whether and how to use these scenarios to develop policies and strategies (cf. Schomberg/ Pereira/ Funtovicz 2006).

8.4.3.2 Academic ambitions of CIB&S—with a positivist undertone

In general, combined scenario methodologies, and in particular those of the SAS type in the field of environmental research, have *academic* ambitions, as described by van Asselt et al. (2010). Especially mathematical modeling and simulation are frequently founded on current knowledge of past and present developments. Following van Asselt and colleagues, this foundation reveals the positivist historic deterministic paradigm that contradicts the constructivist basic assumptions of a multiplicity of futures underlying the scenario idea. In this study, in both cases, a tendency to think in projections of past trends rather than in alternative future scenarios was indeed visible. In the Lima Water case, this tendency was clearly stronger with regard to the *numerical* scenario assumptions than with the initially *qualitative* ones. This phenomenon points at the underlying ontological and epistemological hybridity of all combined scenario methodologies. This hybridity results in tensions and thus, combined scenario approaches risk providing rather ambiguous forms of modes of orientation (in the sense of Grunwald 2013), see section 2.4.1.

In combined scenario methodologies using *CIB*, this academic ambition becomes more prominent than in SAS. IL, initially stemming from business applications, is added to or replaced by CIB, a systematic method with mathematical foundations and academic credibility. Its benefits, as this study has shown, [434] are mainly to support the levels of scenario traceability and scenario consistency, which are academic quality criteria. In consequence, the strong clash of cultures identified between the two components of SAS is a little weaker in CIB&S, as the degree formalization of both components is more converging and as both components belong to the realm of academia.

Does this tendency of combined scenario methodologies to stress the academic through the use of CIB enforce their positivist tendencies? The risk is certainly there, and the approach was perceived as such in the LiWa project, as an article reflecting on the project by Miranda and Baud (2014) reveals. But the risk is not unavoidable, because what is considered scientific and academic was and still is changing. Applied, participatory, transdisciplinary approaches, based on constructivist rather than on positivist paradigms, have found their place in academia, too. Still, it might depend on how CIB and CIB&S are not only designed but also framed, promoted and understood by their users, namely either in a more positivist or in a moderately constructivist way.

The issue of academic ambitions of CIB&S, and of other combined approaches, is linked to the general questions, on how to solve the tension between the diverging epistemological perspectives of models and of qualitative scenario approaches. One possible approach is to strive for what Grunwald calls the "mode 3 type of orientation" of futures studies. With CIB&S this could mean that CIB is systematically used in the form of a joint conceptual model, by all actors relevant to the scenario construction. It might then make it possible to reveal the reasons for and sources of divergent present assumptions, ideas, normative positions and beliefs, also implemented in the mathematical models, that lead to the "divergence of futures" (Grunwald 2013a: 30). This is probably possible only in those forms of CIB&S that require and realize high degrees of openness and explicitness with regard to future and model assumptions.

8.4.3.3 The scope of application of CIB&S

The use of CIB within integrated scenario methodologies has specific functions and a specific scope of application—but is no all-in-one device, suitable for every purpose. One, I consider that CIB&S is an appropriate method to support interdisciplinary teams to construct exploratory qualitative *and* quantitative or integrated scenarios of socio-environmental systems. It provides a new approach to environmental researchers and futures researchers, i.e. to the future-oriented actors in environmental research and the environment-oriented futures researchers, to think through possible futures and therefore, to support their policy advice. As ongoing applications in the field of energy research sug-

[434] This study itself is a symptom of the increasing scientification of futures research. And next to the perceived relevance, this thesis was also motivated by purely academic pleasures and interest in reflecting scenario methodologies.

gest, the approach seems not only appropriate for the construction of socio-*environmental*, but also of socio-*technical* scenarios.

Two, the approach clearly is situated within futures *research*, with the primary aims of academic exploration and reflection. It is no pragmatic or corporate foresight tool and also clearly opposite to creative realms as art, design or science fiction, which are useful for futures studies and foresight, too—but in very different ways.

Three, I consider CIB&S as being an *expert* approach—in contrast to a stakeholder or laypeople approach, even if in the Lima Water case, stakeholders had been included in the scenario group. The approach requires quite some expertise and capacities with regard to the CIB and, within more deeply integrated versions, with regard to mathematical modeling and simulation, too. Experts from various disciplines, however, can strongly benefit from the approach, to reflect their own mental models, and to support inter- and transdisciplinary communication about these models.

Overall, CIB&S methodologies are more structured and more systematic than SAS-type methodologies. This gives them certain strengths with regard to traceability and consistency. CIB&S seems to be most appropriate for analyzing, reflecting on and structuring existing assumptions and ideas for possible futures. But it does seem less suitable for supporting our creativity with regard to our futures—and does not seem appropriate, when very flexible and inclusive scenario processes are required. In sum, CIB&S has a specific scope of application within the broad spectrum of futures studies and foresight activities. The central functions of the use of CIB within integrated scenario methodologies are to discuss socio-environmental futures among experts and to systematically think through present ideas on possible future developments[435] of our interdependent societies and environments.

[435] In the sense of Grunwald (2011).

Chapter 9: Constructing more traceable and more consistent scenarios

To conclude, I summarize the approach of this study (9.1) and its central findings (9.2). Finally, I point at limits of this study and at avenues of further research (9.3).

9.1 Overview of the approach of this study

This thesis dealt with new forms of combined and integrated scenario methodologies that have been proposed for the field of socio-environmental scenarios. The aim of this thesis was to explore, whether and how the use of the CIB, a qualitative systems analysis technique, within combined scenario methodologies—especially in forms of CIB&S—could support interdisciplinary research in the construction of qualitative *and* quantitative or integrated exploratory scenarios of socio-environmental systems. To reach this goal, I strove for the perspective of a reflective foresight practitioner; and I applied the case study approach to fully exploit my insider perspective on the two first demonstrator and pioneer applications of the use of CIB combined with numerical modeling and simulation (CIB&S). These applications were carried out in the field of environmental modeling and model-based scenario building as well as in the field of water management. My intention was to have a very close look at these first applications, to take a step back to reflect on and conceptualize these applications, to then turn back to practice to give information of effects of the use of CIB within different forms of combined scenario methodologies and of the factors influencing these effects. In this study, the conceptual and empirical perspectives were closely interlinked. Nevertheless, the work carried out during this study can be summarized in three phases.

In the first phase, this study has established the state of research on combined scenario approaches and on CIB as a qualitative form of systems analysis and qualitative scenario technique. Facing the difficulties of combined scenario approaches of the dominant SAS-type, using CIB had been proposed but neither systematically empirically analyzed nor yet conceptually grounded. The literature suggested that using CIB might be especially beneficial for supporting combined scenario approaches in view of the difficulty they have in ensuring the traceability and consistency of scenarios. Based on this literature review, a conceptual framework on combined scenario methodologies using CIB (CIB&S) was developed to help think through the new approach and to prepare an empirical analysis. CIB&S processes were conceptualized as idiosyncratic scenario methodologies in which many factors such as different methods, actors and data (in the widest sense) are combined and jointly structure and shape scenario processes and their scenario products. Several conceptual elements were derived and further operationalized to allow the description of CIB&S processes based on a process scheme; to characterize idiosyncratic methodologies with regard to their social organization, technical design and data; and to characterize forms of the combination of CIB with numerical modeling and simulation with regard to the systems representations, the relative position of both components, as well as the type and degree of the links between both components. A working definition of scenario traceability was developed to assess CIB&S scenario processes and products. This definition comprises the traceability of assumptions on future developments and their interrelations as well as of the composition of individual scenarios and of scenario samples, and distinguishes between traceability from internal and from external perspectives. Also, a working definition of scenario consistency was proposed. It distinguishes between four levels of consistency, namely the internal consistency of individual scenarios; consistency within scenario samples; consistency between different, e. g. qualitative and quantitative, forms of scenarios; and consistency of underlying numerical, conceptual, mental models. For the empirical analysis, three research questions were specified and my expectations were made explicit.

In the second phase of the study, two exploratory case studies were designed and carried out. The first case (UBA, in 2010/2011) was a demonstrator application of the use of CIB to construct framework data sets ("Germany 2030") for a group of environmental models. The second case (Lima Water, 2010-2013) was a full pioneer application of CIB within a combined scenario process resulting in integrated (qualitative-quantitative) scenarios called "Lima's water management futures 2040". From both cases, empirical data was collected by using three sources of evidence, namely participant observation, semi-structured interviews with case participants, and process documents.

In the third phase, both cases were analyzed individually through qualitative data and content analysis. This analysis was guided by my conceptual framework and expectations. The overall data analysis strategy was to first describe the individual methodologies and forms of the combination of CIB with modeling and simulation (the independent categories). Second, the levels of traceability and consistency and of other intended or unintended effects with regard to the process and products were assessed (the dependent categories). Third, by interpretation, I established plausible links between the levels of traceability and consistency and other phenomena on the one hand, and the methodology and its form on the other. I did so by argumentatively separating the influences of CIB, its interplay with other elements and the (independent) impact of other elements. Draft reports of individual cases were reviewed by key informants in the respective cases. Then, findings of the UBA and the Lima Water case were compared. This was supported by a comparison with the initial expectations. To answer the research questions, generalizing insights were summarized, discussed and validated by experts.

Finally, the quality of the design, of the collected data and of the findings of the empirical part of this study, as well as the usefulness and transferability of the conceptual framework were discussed. The findings of the study were confronted with the state of research on CIB and on combined and integrated scenario methodologies, and the scope of application of CIB&S methodologies was precisely situated in futures research.

9.2 Central findings

The empirical analysis of the UBA and the Lima Water case showed that the two cases had very different contexts, realized different combined forms and methodologies with fairly different social, technical and cognitive organization. In both cases, some of the expected traceability and consistency effects of CIB within the combined scenario methodologies were reached. Although the cases appeared rather dissimilar, the patterns of the interplay of CIB with other factors leading to these were rather similar or at least complementary. The same similarities were found in other effects, namely regarding new checks and balances among modelers, scenario groups and scenarios experts and regarding issues of effort, flexibility and creativity.

For synthesis, I argued that both cases can be considered prototypes for a typical use of CIB within combined scenario methodologies (type CIB&S). I reasoned that both, the relative position of CIB and the numerical modeling as well as the type and degree of integration between both play a decisive role in these functions. I generalized my findings into a typology of forms of the combination that can support interdisciplinary research groups in different ways, meaning through different functions of CIB. Depending on the position of the CIB and from the degree of integration between CIB and modeling, four ideal-type forms and functions are plausible; see Table 41, identical with Table 40 in chapter 8.

Table 41: Functions of CIB in ideal-typical forms of combined scenario methodologies

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Integration (overlap, link, iteration, inclusion)</td></tr>
<tr><td>low</td><td>high</td></tr>
<tr><td rowspan="2">Position
(timing, impact on scenario content and structure, benchmark for adaptations)</td><td>Models first</td><td>type 1
CIB proposes general context scenarios to a model or a model group in the form of a non-committal, additional service.</td><td>type 2
CIB as an integrated analyst and provider of tailored framework assumptions for a model or a model group.</td></tr>
<tr><td>CIB first</td><td>type 3
CIB as a steersman of a qualitative scenario process; models provide additional numerical information.</td><td>type 4
CIB is jointly used by a scenario- and modeling team to build a joint conceptual model as a base for integrated system scenarios.</td></tr>
</table>

The empirical study of the UBA and Lima Water cases shows that CIB&S provides some new answers to the challenge of traceability of SAS: Most notably, CIB supports the traceability of assumptions on future (societal) developments in the raw CIB scenarios as well as in the derived narrative, numerical and integrated scenario forms. But this study shows that CIB is not easy to understand, either for internals or for externals. This directly challenges its traceability effects. Furthermore, scenario traceability in both cases was influenced by issues of the social organization, especially by the inclusion of actors, as traceability for externals to the CIB is far more difficult to achieve; and by issues of accessibility of documentation, especially of assumptions on interrelations and of the sampling. Finally, using CIB can have traceability effects for non-modelers with respect to numerical models and, in consequence, with respect to the numerical scenarios. With this in mind, the model structures, e. g. causal interrelations underlying model outputs, and simulation decisions need to be revealed and compared. This effect is more to be expected in combinations with a high degree of integration (design types 2 and 4). The position of CIB does not seem to play a direct role in traceability effects. Overall, my findings suggest that combined scenario methodologies using CIB have certain new answers to the traceability challenge that more classical SAS approaches are confronted with. Nevertheless, some issues still remain, especially with regard to maintaining the accessibility of assumptions of interrelations that are revealed during the CIB.

The UBA and the Lima Water case show that scenario consistency is dealt with differently in CIB&S from the way it is handled in SAS. The promise of consistency is reversed, since the task to ensure internal consistency of qualitative scenarios is handed over to the CIB. If the CIB balance algorithm is used to compose individual scenarios, then internal consistency of these scenarios (according to the CIB consistency criterion) is ensured. If all scenarios of a chosen sample are based on the same CIB matrix, then there is additionally also consistency within this sample. In integrated scenario processes, this consistency of the raw CIB scenarios can propagate to the narrative storylines and to the sets of numerical input data, and thus supports the consistency between different forms of scenarios. But in both cases, I found evidence that the application of CIB alone does not guarantee the propagation of consistency. Instead, this does require further methodological elements, namely especially the use of CIB-generated data and the support (and consistency check) through CIB actors, who defend the CIB scenario definitions and the CIB consistency criterion as a benchmark. Consistency between different (raw, qualitative and quantitative) forms of scenarios is nothing automatic either and was, in the Lima Water case, achieved rather on the level of appearance. Achieving consistency in the underlying models is a more ambitious and demanding endeavor requiring a high degree of integration between CIB and the mathematical model(s)—which perhaps is neither always possible nor necessary (cf. CIB&S types 1 and 3). Thus, consistency effects are influenced rather more by the degree of integration, too – and less by the relative position of the CIB.

With regard to other effects, this study has shown that the use of CIB creates new checks-and-balances within integrated scenario methodologies, since the task of (intuitively) composing scenarios and samples is taken from the hands of scenario groups and modelers and handed over to the CIB and the CIB scenario experts. Furthermore, using CIB in integrated scenario methodologies requires additional resources. Its systematic character and the necessary CIB method expertise might challenge the flexibility of the scenario process. When the overall scenario process has other than mainly exploratory aims and depending on the intended type of storyline products, it might require additional creative and explicitly normative counterweights. These other effects seem to be influenced mainly by the relative position of the CIB within the process and less by the degree of integration.

The *conceptual framework* developed in this study has proved useful overall. Especially the refined CIB&S processed model and the typology of four functions of CIB in different forms of its combination are further recommended to orient the design and analysis of further empirical applications of different forms of CIB&S. The conceptual dimensions used to characterize scenario methodologies and forms of combined scenario methodologies proved useful, too. They seem generalizable to characterize combined scenario approaches in general, meaning also those not combining CIB, but other forms of scenario techniques**.** The working definitions and operationalization of scenario traceability and scenario consistency are a starting point, pointing at one path toward more scenario-specific quality criteria in the current quality debate in futures research.

Overall, in response to my initial research question, I would like to argue that using CIB within integrated scenario methodologies is a new approach to support actors in socio-environmental studies and futures research. CIB can be integrated into different forms of scenario methodologies that use numerical modeling and simulation. In different combined forms, CIB fulfills different functions within the scenario process. Its effects on scenario traceability and scenario consistency increase with the degree of integration that is achieved within the scenario methodology.

With all due caution, comparing CIB&S to modeling only and to SAS-type approaches offers the following benefits.

- First, CIB&S methodologies structure the *interdependency* and *complexity* of socio-environmental futures without requiring their overall mathematization. They apply systems thinking to the qualitative and non-calculable aspects of any combined system, such as socio-environmental and socio-technical systems, too. By conceptualizing and simplifying these as impact networks, interrelations move to the center of attention. The approach can at the same time be used to consider interrelations between social and environmental and technological systems—as well as interrelations *within* each of these domains, at least in a qualitative way. Accounting for the complexity of socio-environmental futures, CIB supports or at least monitors the internal consistency of qualitative scenarios as well as the consistency between different narrative and numerical forms of scenarios.
- Second, CIB&S methodologies provide a more traceable approach to translate future *openness* and *uncertainty* into alternative scenarios. They embed model based scenarios in explicit, qualitative sets of assumptions on future (context) developments—and thus support the usability and potentially also the policy relevance of model results. At the

same time, they anchor qualitative scenario samples in explicit and accessible conceptual models—and thus support the discussion and critique of storylines, too.

- Third, CIB supports dealing with the interdisciplinary challenges resulting from the *hybridity* of integrated scenario methodologies. If the so to say imposition and the effort required for participation in the CIB are accepted, CIB makes it possible to process and integrate different forms of present assumptions, knowledge and ideas on alternative possible futures in the form of the conceptual CIB model. Such CIB models can be considered bridges between qualitative and quantitative system representations and their scenarios. They can support inter- and transdisciplinary scenario teams through the use of CIB as a shared meta language (cf. Hinkel 2007) to better communicate with one another across disciplinary, methodological and also epistemological borders. This supports the continued development of understanding of the respective systems and helps researchers arrive at more comprehensive and better integrated socio-environmental scenarios.

In sum, using CIB within combined scenario methodologies allows the construction of better scenarios by embedding model generated scenarios into more traceable and internally consistent bundles of qualitative assumptions on future (social) developments. The central benefit for the *participating experts* is that the approach supports them in better analyzing, structuring and reflecting their assumptions, knowledge and ideas on possible future developmen*ts* of our interdependent societies and environments. For the *external recipient users* of the scenarios resulting from CIB&S, the central expected benefit is that the assumptions on future uncertainty and complexity underlying different qualitative *and* quantitative or integrated scenarios become more accessible and critiquable. This is a prerequisite for credible and usable information—and might support the potential impact of combined scenarios in policy-advice.

9.3 Limits and further research

This exploratory study has not only answered questions, but it has also prepared avenues for further research.

This study provided empirical hints that the systematic consistency criterion by CIB does not automatically match with the more subjectively perceived consistency or plausibility criteria of its users. This needs to be further explored, both empirically and conceptually. Furthermore, evidence was rather weak with regard to traceability and consistency *needs* from different internal and external user groups. Therefore, a systematic empirical analysis is required on who (modelers, scenario group, members, scenario experts, different types of externals) needs to trace what at what moment in the process and what can remain black boxed; and who needs what degree of consistency in what situations. This in turn leads to the question of whether and exactly how the academic criteria of scenario traceability and consistency are linked to practical usefulness and credibility, as well as the reception and policy impacts of combined scenarios (cf. e. g. Schomberg/ Pereira/ Funtovitcz 2006).

Regarding the design of this study, tracing the effects of one method, CIB, within complex and idiosyncratic methodologies in a qualitative way was feasible, but to a high degree reliant on interpretational work. Results need to be validated through further empirical research. Finally, this study strove to attain the research position of the consciously reflective foresight practitioner. Using case study research seems to be one possible approach, though it was challenging since it required dealing with multiple roles and bias. Therefore, I recommend that there be further explorations into how to methodologically and conceptually support reflexive practitioners in the field of futures studies.

The concepts developed in this study need to be further developed and their generalizability needs to be empirically tested. This study provided working definitions of scenario consistency and scenario traceability. These are a starting point. I recommend strengthening them through the theoretical sources not only provided by scenario literature, but also by fields such as modeling, cognition and communication research, philosophy and mathematics. Moreover, it seems promising to apply and potentially adapt the newly developed typology of forms of the combination to characterize *combined* (type 1 and type 3) and *integrated* (type 2 and type 4) scenario methodologies using other approaches to qualitative scenarios than CIB.

Then, there are several *methodological* issues with regard to the implementation of combined scenario methodologies using CIB. This study has given several hints as to what is required to realize a successful matching on the level of scenarios, meaning the translation between raw CIB scenarios and numerical input data sets. Crucially, it is still open how to socially organize, technically design and cognitively support systematic and explicit forms of matching on the level of underlying models, that is between a conceptual CIB model and a numerical simulation model or models. Using CIB as a joint conceptual context or system model, which is the necessary precondition for reaching methodologies with very high degrees of integration (as in type 2 and type 4), will require developing new modes of comparison and adaptation of inter- and transdisciplinary models.

Furthermore, this study allowed glimpses into two further avenues of research that could be fruitful in the effort to further diversify the field of combined scenario methodologies beyond the dominant SAS approach. The first avenue would be to use the systematic CIB together with holistic and explicitly creative-normative scenario approaches (visions, utopias etc.) to complement their perspectives. Such a combination of CIB and creative visions would form an entirely qualitative type of combined scenario methodology—or explore the role of CIB as a bridge between creative imagining or visions on the one hand and numerical models on the other hand. Second, this study was focused on the dominant SAS type approach that has framed the derived CIB&S approach. Thus another interesting avenue would be to reconsider the organization of the relation of the qualitative and the quantitative in hybrid scenario methodologies more fundamentally. Reconsidering questions of dominance vs. equality, integration vs. combination, and discussing approaches for dealing with the epistemological divide might help us to benefit best from the specific advantages of different components.

In sum, to deal with the challenges of future socio-environmental change, integrated exploratory scenarios of highest possible academic quality certainly have their role to play. Still—especially to support joint decision making and action—exploratory, academic and expert-based forms of integrated scenarios do not seem sufficient. In addition, and potentially in combination, participatory scenario approaches and perhaps also utopian methods (Levitas 2013) are required. These are necessary to support out-of-the-box thinking, but first and foremost to encourage democratic deliberation on values and meaning, i.e. fundamentally *political* visions, focusing on how we might imagine living together in more sustainable ways. Finally, the critical reflection and analysis of exploratory-descriptive and of explicitly creative-normative forms of current futures maps—and of combinations of both of those forms—could also provide important means of orientation.

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Annex

Annex A Explorative interviews to establish the state of research

These interviews have been conducted in 2010 in the USA and in Germany:

- **Environmental modelers at the juncture of environment and society** (n= 5)
  - Prof. Jerry Melillo, Marine Biological Laboratory (MBL)
  - Dr. Brian O'Neill, National Centre for Atmospheric Research (NCAR)
  - Prof. Matthias Ruth, University of Maryland
  - Dr. Sheila Walsh, Environmental Change Initiative (ECI), Brown University
  - Dr. Axel Winterscheid, German Federal Institute of Hydrology (BfG)
- **Scenario experts** (n= 6)
  - Dr. Eric Kemp-Benedict, Stockholm Environmental Institute (SEI)
  - Prof. Stacy VanDeveer, University of New Hampshire
  - Dr. Elizabeth Malone, Joint Global Change Research Initiative (JGCRI)
  - Dr. Paty Romero-Lankao, National Centre for Atmospheric Research (NCAR)
  - Dr. Vanessa Schweizer, National Centre for Atmospheric Research (NCAR)
  - Dr. Wolfgang Weimer-Jehle, ZIRIUS, University of Stuttgart

Annex B Process of combining qualitative scenario techniques with numerical simulations by different authors

"Story and Simulation" (SAS) (Alcamo 2001; 2008: 138)	**"Qualitative-quantitative scenarios"** (Döll 2003/2004: 399 et sq. own translations)	**"Hybrid scenarios"** (cf.Winterscheid 2007: 171 et sq., own translations)
1)"A scenario team and a scenario panel are established. 2)The scenario team proposes goals and outline of scenarios. 3) The scenario panel revises goals and outline of scenarios, and constructs a first draft of the storylines. 4) Based on draft storylines, the scenario team quantifies the driving forces of the scenarios. 5)Based on assigned driving forces, modeling teams quantify the indicators of the scenarios" 6)The modeling team reports on the quantification of the scenarios and the scenario panel revises the storylines . 7) Steps 4 to 6 are repeated until an acceptable draft of storylines and quantifications is achieved. 8) The draft scenarios are distributed for general review. 9) The scenario team and scenario panel revise scenarios based on general review. 10) The final scenarios are published and distributed."	"1): Identification of the problem statement as well as of participants at the scenario process (researchers and stakeholder). 2) Definition of the system (components, drivers), including the geographic and temporal scope and resolution (base year, time horizon, scenario regions. 3) Definition of the indicators of the system state (depending from the mathematical models available for the quantification). 4) Historical analysis of the development of the system indicators and their driving forces. 5) Development of qualitative scenarios in form of storylines 6) Development of quantitative scenarios. a) Quantification of driving forces. b) Calculation of indicators via mathematical models. 7) Assessment of the scenarios." "Ideally, the scenario process is iterative. The quantitative analysis in step 6 can reveal inconsistencies in the storylines (step 5) that then are modified. Or a first assessment (step 7) leads to the definition of new interventions, then steps 5-7 are carried out again."(Döll 2003/ 2004: 401, my emphasis).	Phase 1: systems analysis. Phase 2: a) Construction of the qualitative scenario parts. b) Selection and preparation of the model. c) Quantification of qualitative scenario parts. d) Simulation run. Phase 3: a) Iterative refinement of qualitative scenario part and quantitative scenario part, explicit reference to SAS (Alcamo 2001). b) Addition of input data sets according to interventions (policy measures). c) Evaluation of scenarios with regard to predefined (sustainability) criteria. Phase 4: documentation and communication of results to different audiences.

Annex C Different techniques to translate qualitative stories into quantitative model input

	Verbal-argumentative transformation	**Fuzzy logics**	**“Bayes’ rule & pundit’s wager”**
Reference	Winterscheid 2007	Alcamo 2008	Kemp-Benedict 2010
Basic logic	Qualitative statements are replaced by numerical data by *reasoning, comparison, analogies*	Bandwith of numerical assesments attributed to qualitative statements is understood as fuzzy definition (*fuzzy set theory*). Defuzzification to obtain numerical point values	Describes the difference of a parameters’ future development compared with a reference development, i.e. through geographical and/or historical analogies (*Bayes’ theorem*).
Technique	Linguistic statement is translated by argumentation, deduction or specification of: • Indicators • Data (distributions) • Values for specific cases Plausibility, existence and accessibility are important criteria for the choices to make. Often: reference to other predicions, scenarios, trend extrapolations etc. from credible sources as e. g. global scenario exercises.	1) Linguistic statement, e. g. „medium population growths“ 2) Different experts give numerical values that fit the development and their „degree of belief“ for each judgement. The data is collected as a membership function (representing the bandwith of assessements), Fuzzy set theory: Defuzzification. 3) The “least ambiguous value” is chosen as numerical data input for ‘hard‘ models (point values). 4) Translation from model results into linguistic statements via membership functions as translation keys.	1) Choose data from an appropriate (prior probability distribution of the parameter) reference case. This distribution should be describable in words, and broken down into discrete steps labeled qualitatively (“low”, “medium” etc.). 2) Define a likelihood ratio, describing the subjective probability, that the development will unfold in the way described, e. g. in linguistic terms: “very likely” or “unlikely” (logarithmic scale behind).
Experts’ role	Experts “best guess” , i.e. judgement, assessment necessary: implies choices and subjective elements.	Experts attribute numerical values to qualitative statements and assess their degree of certainty of this judgement. No consensus necessary. Dissens is used to represent a bandwith of numbers representing a qualitative statement. Experts’ “best guess”, i.e. judgement, assessment necessary: implies choices and subjective elements.	Expert(s) assesses the probability not directly of a future development but of the matching of a future development with a prior distribution. This is used to define a bandwith of numbers representing a qualitative statement. Experts’ “best guess,” i.e., judgement, assessment necessary: implies choices and subjective elements.

Annex D Overview on empirical experiences with combined scenario appraoches

Overview on empirical experiences with combined scenario approaches in different fields (black type =climate and energy, blue type= water, dark green type = sustainability, green type = biodiversity, brown type = land use)

Nr	Name of the project	Short title	When/ Duration	Who (initiating/ funding institution)	Authors, literature	Geographic scale	Time horizon	Theme(s)
1	**Special report on emission scenarios (SRES)**	SRES	1997-2000	Intergovernmental Panel on Climate Change IPCC	Nakicenovic / Alcamo et al. (IPCC 2000)	Global	2100	Socio-economic drivers, GHG emissions, climate impacts
2	**The World Water Vision Scenarios**	WWV	1997-2000	World Water Council	Gallopin/ Rijsberman 2000	Global	2025	The world water situation in 2025
3	**Global Scenario Group, Great Transition Initiative**	GSG	1995-2002	Stockholm Environmental Institute SEI, Rockefeller Foundation, Nippon Foundation, United Nations Environment Programme	Gallopin et al. 1997, Raskin et al. 1998; Raskin et al. 2002 "Great Transition"	Global (11 world regions)	2050/ 2100	Branch points: Global Scenarios and Human Choices
4	**Millennium ecosystem assessment**	MEA	2001-2005	United Nations initiative / long list of donors	Carpenter et al. 2005, (methodological justification in Raskin et al. 2002, methodology in detail in Alcamo/ Van Vuuren/ Ringler 2005)	Global and regional (multi-scale)	2050	The State of World Ecosystems and Human well being
5	**Global Environmental Outlook**	Geo4	2002-2007	UNEP United Nations Environment Program	Rothman/ Agard/ Alcamo 2007	Regional and global	2015-2050	Environment and Sustainability, Global futures
6	**Integrated Visions for a Sustainable Europe**	VISIONS	1998-2001	EC European Comission	Rotmans et al. 2000	Europe and regional	2020 and 2050	Equity, employment, consumption, and environmental degradation water, energy, transport and infrastructure
7	**The future impacts of Information and Communication Technologies**	ICT	2003-2004	Institute for prospective technology studies (IPTS), European Commission	Hilty et al. 2006, Erdmann/ Hilty 2010	Europe	2020	ICT use and its impact on environmental indicators mainly GHG
8	**Policies for Land Use to Combat Desertification (➔ case Guadalentin only)**	MedAction	2001-2004	European Commission	Kok/ Van Delden 2009 ➔ Guadalentin case only	Multi-level: European, Mediterranean, local	2030	Desertification in the Mediterranean region.
9	**Advanced Terrestrial Ecosystem Analysis and Modeling**	ATEAM		European Commission	PIK 2004, Rounsevell et al. 2005	Europe (EU 15)		Future scenarios of European agricultural land use

Nr	Name of the project	Short title	When/ Duration	Who (initiating/ funding institution)	Authors, literature	Geographic scale	Time horizon	Theme(s)
10	**Discussing the future of rural Europe**	EURURALIS	1.0 until 2005 2.0 until 2008	Dutch Ministry of Agriculture, Nature and Food quality	Westhoek/ van den Berg/ Bakkes 2006	European Union (EU 25)	2030	Future of Europe's rural areas
11	**Prospective environmental analysis of land use development in Europe**	PRELUDE	2005-2007	European Environment Agency EEA	EEA 2007b (technical report) and Volkery et al. 2008	Europe	2035	Land use
12	**Water Availability and Vulnerability of Ecosystems and Society in Northeastern Brazil**	WAVES	1997-2001	Federal German Ministry of Education and Research, Conselho Nacional de Desenvolvimento Científico e Tecnológico	Döll/ Krol 2002, Döll 2003/2004	Regional (Brazil)	2025	Regional development focussing Water availability and water usage; (Water, Agriculture, Land use, Migration)
13	**Flood Foresight and Coastal Defense**	FFCD	2002- 2004	GB, national Foresight program; Department for Environment, Food and Rural Affairs	Government Office for Science 2004; Wheater/ Evans 2009	National (Great Britain)	2080 2100	Flood risk
14	**Development of flood management strategies for the Rhine and Meuse basins in the context of integrated river management**	IRMA	1997-2001	European Commission INTERREG II, NRP	van Asselt et al. 2001a, van Asselt et al. 2001b	Regional (Rhine and Meuse)	2050	Flood risk in catchments of rivers Rhine and Meuse
15	**Water scenarios for Europe and neighbouring states**	SCENES	2006-2011	European Commission	Kämäri/ Alcamo et al. 2008; Vliet/ Kok 2008, Vliet et al. 2012	Pan- European, regional, watershed scale	2025 2050	European freshwater futures
16	**Energy Modeling Forum Project 21 : Multi-Gas Mitigation and Climate Change**	EMF	(?)	European Commission	Böhringer/ Löschel 2005	Global	2020	Climate policy and its economic effects
17	**ClimPol B2: Energy strategy of a rural community**	URNÄSCH	2008-2009	ETH Zurich	Trutnevyte/ Stauffacher/ Scholz 2011	Local (community level)	2035	Energy strategies
18	**ClimPol B2: Context-specific energy strategies**	APPENZELL	2011	ETH Zurich & Canton Appenzell Ausserrhoden	Trutnevyte et al. 2012	Local (small state level)	2035	Energy strategies

Annex E Characterizing empirical examples of combined scenario appraoches

Characterizing the combined methodologies of the empirical examples
(black type =climate and energy, blue type= water, dark green type = sustainability, green type = biodiversity, brown type = land use)

Nr	Short title	Main purpose(s)	Qualitative scenarios (technique; participants)	Model(s)	Division of labor; overlap	Dominance	Timing	Coupling, feedback/iteration
1	**SRES**	Exploration Policy advice (used in assessment reports 3 and 4)	IL, scenario axes. International expert group	Emission models, coupled global climate models (atmosphere, ocean, sea ice, land surface)	Social and economic dimensions vs. natural dimensions. Overlap weak, storylines provide context assumptions.	Scenarios as basic assumptions for model runs, models dominant (preexisting)	Consecutive process quantified storylines as input parameter	One-way input-output, no iteration
2	**WWV**	Communication (to raise global awareness about global water problems and solutions, targeted at large public and also scientific audiences)	BAU plus two more scenarios (intuitive). Scenario panel plus large participation of professionals and regional stakeholders.	Simulation models, e. g. WaterGAP, demographic models	Storylines: drect and indirect drivers of the future world water situation: (extent of irrigated land, level of water supply infrastructure, population and economic growth. Modelindicators on water use and water availability.	Storylines as main vehicle, numerical modeling for backup.	Storylines first	Feedback and iteration between qualitative and quantitative scenarios.
3	**GSG**	Communication Awareness Exploration Policy advice	Intuitive, two tier: 4 classes (archetypes, explicitly normative) with 2 variants each; Expert panel	Polestar (global, modular model incl. social, economic, and environmental elements)	Scenarios cover all, supported by simulation model. Complete overlap, scenarios with broader scope.	Qualitative. scenarios dominant	Scenarios first, quantified and simulated	Mutual feedback; translation of storylines (hard input-output link).
4	**MEA**	Exploration Policy advice	Intuitive & participatory Scenario panel plus survey among users	Global model comprising n= 5 coupled (integrated) ecosystem models: IMAGE, IMPACT, WaterGAP, Ecosim, AIM	Qualitative vs. quantitative (scientific clarity & narrative richness); Storylines provide shared context assumptions for model group. Overlap strong, storylines include environmental factors and impacts.	Cooperation (incl. equal time effort)	Storylines first	Storylines provide shared context assumptions; reciprocal information, iteration.
5	**Geo4**	Exploration Policy advice	Intuitive & participatory, based on Geo3 and GSG storylines	Group of global and regional models: International Futures, IMAGE, IMPACT, WaterGap, EwE, GLOBO, LandSHIFT, CLUE-S, AIM	Narratives: key drivers of environmental change: institutional an socio-political frameworks, demographics, economic demand, markets and trade, scientific and technological innovation and value systems. Quantitative indicators for illustra-	Qualitative narratives take center stage with the quantitative tools playing a supporting role.	Parallel	Iteration initially planned but abandoned due to lack of time; no hard link.

Nr	Short title	Main purpose(s)	Qualitative scenarios (technique; participants)	Model(s)	Division of labor; overlap	Dominance	Timing	Coupling, feedback/iteration
					tion and scenario (pattern) comparison.			
6	**VISIONS**	Exploration Awareness Policy advice	Intuitive logics (actors, factors, sectors) Stakeholder participation (Different designs on EU level and in the three regional cases→ bottom up)	EU level: Worldscan, PHOENIX	Overall: Sense making vs. scientific rigor.	EU level: Visions dominant, model supporting	EU Level: Visions first	EU level: Soft link
7	**ICT**	Exploration Policy advice	Intuitive; Desk research & expert validation	Newly built SD Model of relations between ICT applications and environmental indicators	Model: Technolgy & Environment, Storyline: Everything else (socio-economic & political). Overlap weak, storylines provide context assumptions and range of future developments.	Model rather dominant	Consecutive, storylines first and independent, model developed in parallel	Output-input link, iteration
8	**MedAction**	Exploration Communication Policy advice	Top-down approach 1. Europe (based on the VISIONS scenarios,2. downscaled to Mediterranean, 3. Input into local scenario development. At local level: Participatory stakeholder Workshops (local, non-scientific key stakeholders, decision makers, poets, farmers) & researcher decision.	Spatial DSS (PoSS); sub models: land use, climate and weather, hydrology and soil, farmers decisions, vegetation, water management	Storylines: fears, hopes, expectations and future uncertainty, DSS: rational analysis, Policy support system (PoSS).	Equal	Parallel	In part quantification of storylines and used as input configurations for PoSS.
9	**ATEAM**	Exploration	Interpretation of four SRES marker scenarios: qualitative definition of drivers	Supply-demand model, IMAGE, ATEAM grid (spatial allocation)	Storylines as context information on (model external) drivers, system representation by models	Quantitative modeling and visualization central.	Parallel (?)	Output-input link from storylines to models.
10	**EURURALIS**	Policy advice Exploration	Scenario axes to construct storylines	Using a cascade of models from global	Qualitative scenarios providing (global) context uncertainty and	Quantification was central	Storylines first	Output-input link from storylines to models;

Nr	Short title	Main purpose(s)	Qualitative scenarios (technique; participants)	Model(s)	Division of labor; overlap	Dominance	Timing	Coupling, feedback/iteration
			Relying on existing studies, expert & desk research based	models (LETIAP/ IMAGE) to spatially explicit 1km x 1 km models for visualizing land use in Europe	model input-			Iteration within model group
11	**PRELUDE**	Exploration Policy advice	"Inductive" (combination of factors) Participatory (stakeholders)	Landuse model (Louvain-La-Neuve model) with three components: urban, agricultural, forest land use	Scenarios: drivers of change Modes: system consequences	Stakeholders with high responsibility of co-decision ➔ conflicts "Your vision or my model?"	Storylines first	Iterative (reference to SAS)
12	**WAVES**	(Scientific) exploration Policy advice (strategic planning	Intuitive With participation of policy makers and stakeholders	Integrated model including e. g. NoWUM SIM, RASMO and MigFlow	Narratives provide model contexts: socio-economic developments, , institutional- administrative structure, i.e. the qualitative, social sciences, and the uncertain. Overlap considerable: A) Input parameters= quantified drivers of the narratives B) output indicators = issues of narratives as water scarcity, agricultural production, migration.	Rather equal partners considering the influence on the scenarios	In parallel, qualitative scenario process considering model indicators from the beginning, models in part newly built	Interlinked at several moments of the process, iterative
13	**FFCD**	Exploration Policy advice	Scenario axes combining socio-economic and climate change scenarios	RASP HLM Pressure State Impact Response (PSIR)	Qualitative scenarios providing socio-economic and climatic contexts (drivers from outside the modelled system); modeling for flood risk assessment.	Models dominant (?)	Parallel (?)	Qualitative scenarios providing alternative model frameworks.
14	**IRMA**	Exploration Policy advice	Cultural theory based 'perspective' methods (based on archetypes) to design qualitative scenarios Literature and stakeholder based	Water household models (RHINEFLOW, BEKKEN and NAGROM) as well as, function models and DSS	Qualitative scenarios representing uncertainty and 'perspectives', models "models were used to reason through the perspective-based assumptions into the future, especially pertaining to associated water related effects, which are expressed in quantitative terms" , quantitative comparison of different scenario (consequences).	Qualitative 'perspectives' provide also analytical framework for modelling, models in supporting role	Qualitative scenarios first	Interlinked, qualitative scenarios used for definition of input data sets and model parameters.

Nr	Short title	Main purpose(s)	Qualitative scenarios (technique; participants)	Model(s)	Division of labor; overlap	Dominance	Timing	Coupling, feedback/iteration
15	**SCENES**	Exploration Policy advice Method research	Qualitative, supported by structuring methods as Fuzzy Cognitive Maps (FCM). Participatory	WaterGAP	Models to enrich storylines with numerical information and to provide consistency check.	Equal weight, focus on 'bridge' between qualitative and quantitative: structure and quantification of stoylines.	Storylines first	Fuzzy cognitive maps for quantification of storylines, output-input link, feedback of modeling results into 'enriched' storylines. Iteration (full SAS process)
16	EMF	Exploration (and policy advice)	Probabilistic CIA Expert survey	Computable General Equilibrium (CGE) model (global trade and energy use)	CIA: defining post Kyoto climate policy scenarios. Models: quantification of economic implications and validation of qualitative scenarios.	Equal weight	CIA first	CIA based scenarios used for alternative CGE simulation runs.
17	URNÄSCH	Exploration Policy advice	Visioning workshop with stakeholders and experts Expert & desk research validation	Energy System Modelling (ESM)	Visions: 'the intuitive', i.e .actors' holistic, qualitative and normative vision of the energy system. Model: 'the analytical', i.e. specific and quantitative energy scenarios (technology portfolios).	Equal weight , plus MCA	Visons first	Hard matching,every vision translated into many quantitative scenarios.
18	APPENZELL	Exploration Policy advice	Intuitive Based on media analysis and visioning workshop in one community	Energy System Modelling (ESM)	Visions: general normative ideas and goals for the energy system. Modelling: technical feasible and cost effective technology portfolio.s	Equal weight	Parallel/ simultaneous	Soft matching between qualitative visions and multiplicity of technical scenarios per vision. None is input of the other.

Annex F Assessing (ideal type) scenario approaches with regard to scenario traceability and consistency

Pretest of the criteria: my own rough and ideal type assessments.
Legend: c = consistency; * = consistency criterion: causal relations, i.e. reciprocal impacts of developments.

		A „intuitive logics“	B „model based“	C „SAS“	D “CIB only”
Scenario traceability	Assumptions • On future develop-ments • On interrelations between those	Assumptions on future developments verbally described in form of story-lines and easily accessible to internals and externals, experts and non-experts Assumptions on interrelations based on mental models, rather not (all of them) explicit (especially not for ex-ternals)	In part explicit to experts: input data, internal equations and coefficients can be documented and then accessed by external experts. Beyond these explicit parts, numerical models ‚bury' many further assump-tions that play a role with regard to scenario calculation. Assumptions on interrelations between input parameters (first half of numerical scenarios) often not (systematically) taken into account (= outside model scope).	<u>*Ideally*</u>: *Story*: quantification an simulation make as-sumptions (on future developments and on interrelations) explicit (Alcamo 2008). *Simulation*: Qualitative (framework-) assump-tions (and some of their interrelations) are made explicit in the “story”. <u>*In practice:*</u> Interrelations in storylines only made accessi-ble in numerical m form (i.e. to experts) as far as these are covered by the numerical mod-el(s), too. Quantification and iteration lead to additional assumptions, not automatically explicit to externals and or non-experts.	Assumptions on future de-velopments made explicit for internals & externals, experts and non-experts in form of short definitions of D&V. Assumptions on interrela-tions made explicit (at least) to internals and experts through pair-wise cross-impact assessment.
	• Construction of indi-vidual scenarios • Selection of scenario sample	Often, use of the scenario axes to build four opposing, scenarios, Individual scenario composition ra-ther intuitive, selection of sample either through four field matrix or other means (from theoretical to pragmatic justifications)	Selection of several (individual input data sets (first half of numerical sce-narios), e. g. intuitively, by transfer of reference scenarios (e. g. from the IPCC, UNESCO, world bank) or prag-matically corresponding to client's interests/ normative goals. Calculation of ‘second half’ of scenari-os through model(s), traceable to in-ternals and/or experts only.	1. See A for storylines (individual scenarios and samples) 2. Input data sets are constructed translat-ing the storylines into model relevant input (first half of numerical scenarios) 3. see B for the second half of numerical scenarios 4. Iteration to adjust individual scenario construction and to adjust sample selec-tion	CIB analysis to determine internally consistent configu-rations (depending from level of accepted inconsistencies) Sample based on interpreta-tion and re-grouping of in-ternally consistent configurations (= support only)

		A „intuitive logics"	B „model based"	C „SAS"	D "CIB only"
Scenario consistency*	Internal **c**	Difficult, therefore, often use of consistency analysis to (ex post) assure internal (forma) consistency. Inconsistencies e. g. in IPCC SRES Storylines	Mathematical consistency of modeled system. But c. of framework assumptions at risk when assumptions on interrelations not considered.	See A and B: If the story component is not internally c, the internal c of input data sets is threatened, too. Consistency checks by the model limited to those parts of the storylines that are quantifiable and can be represented by the model.	Can be tested for each possible scenario through the CIB consistency algorithm
	C within a sample	<u>Unintentional</u> inconsistencies possible, e. g. when different storylines are prepared by different groups (e. g. Volkery et al. 2009). Intentional inconsistencies possible to play through e. g. diverging (ideological) perspectives on dynamics/ logic.	<u>Explicit and intentional</u> inconsistencies possible and useful, e. g. to test different assumptions and assumptions on interrelations within one scenario set.	See A and B. If storylines are <u>unintentionally</u> inconsistent, then the consistency within the corresponding sets of input data of the numerical scenarios is threatened.	When the sample is based on internally consistent individual scenarios base d on the same CIB matrix, consistency within the sample is assumed, too.
	C between narrative and numerical scenarios	—	—	<u>*Ideally*</u> Realized, at least with regard to overlap between system representations. <u>*In practice*</u> Bias 1: translation (matching: specification and quantification). Bias 2: missing iteration.	—
	C bewteen underlying models	(Intuitive) Consistency of storylines with mental models of their producer user established through intuitive consistency checks.	(intuitive) Consistency of numerical input data sets with mental models of their producers (the modelers).	Ideally, in classical SAS, the internal structure of the 'models' underlying the storylines is adapted to the internal structure of the numerical models.	Consistency of conceptual CIB model with mental models of their producer user assumed – but not empirically tested yet (possible conflict between intuitive and systematic consistency criteria).

Annex G Overview database case UBA

Process Documents	• Terms of reference UBA • Call UBA • Proposal UBA 20100924 • Minutes kick off 20101019 • PPT kick off • UBA studies for indicator and TS selection • Indicators and time series for selection (EXCEL and WORD) • Minutes video conference 20101029 • CIB matrices over time • PPT final presentation • Final report 201103
Field notes	• FN final presentation 20110120 • FN proposal writing 201009 • FN publication 201101 • FN method questions
Interviews	• Interview UBA expert A • Interview UBA expert B • Interview UBA expert C • Interview UBA expert D • Interview UBA expert E • Interview UBA expert F • Interview UBA expert V • Interview UBA expert W

Annex H Overview database case Lima Water

	(2008-)2010	2011	2012	2013
Process material	• LiWa_proposal • ZB_IWS_ZIRIUS 2008 • ZB_IWS_ZIRIUS 2009 • ZB_IWS_ZIRIUS 2010 • LiWa_MilestoneReport • LiWa_MilestoneReport_Appendi • BleckmarBergen_PPT HK • PPT_CIB Scenarios 20100907 • Linking _scenarios _LiWatool_minutes 20100909 • PPT_LiWatool_ expert Q_20100908 • LiWa matrix No. 4	• ZB_ZIRIUS_IWS_2011 • LiWa matrix No. 6 • LiWa matrix No. 7 • LiWa matrix No. 8 • PPT Linking _Barriers 20110223 • PPT LiWa_WP2b_Scenarioquantification_20110525 • PPT LiWatool_y_Escenarios 20010708 • Scenarioquantification _20110725 • Explanation_Scenarioquantification_ifak _ZIRIUS_20120429	• ZB_ZIRIUS_IWS_2012 • Scenarioquantification_20121206 • Scenarioquantification_20120313 • LiWa Storylines_long 20120315 • LiWa Storylines_short 20120314 • LiWa10en_adaptation after RT II_20120614 • Simulation_Scenarios_A_C_D 20120314 • Simulation_Scenarios_B1_B2_20120410 • Storylines LiWa9 290112_first comments • extern modeler 4 • Scenario table n_16 and first simplification n_8 March 2012 • PPT HK at LiWa meeting Magdeburg 20121025_26 • LiWa matrix No. 9 • LiWa matrix No 10	• LiWatool • Scenario brochure 20130321 • Scenario brochure final 201305 • ZB_IWS_ZIRN_2013 • Descriptor essays final • PPT_ technical meeting_20130306 • Minutes simulations technical meeting by expert O_20130306 • Scenarioquantification_020513 • Scenarioquantification_050313 • Scenarioquantification_180313 • LiWa matrix No.11
Field notes	• FN meeting ifak_ZIRN Stuttgart 20100118 • FN Ifak-HK meeting Magdeburg 20100908 • FN overall project meeting Suderburg 20120412_14	• FN ifak_ZIRN meeting 20110223 • FN project meeting Magdeburg 20110525_26 • FN June_August 2011 • FN March_Mai 2011 • FN November_December 2011 • FN field trip Lima I 201109_10 • FN wizard training I_II_III autumn 2011	• FN January 2012 • FN field trip Lima II March 2012 • FN iteration matrix vs. storylines 20120423 • FN Ifak 20120427 • FN Internal ZIRN meeting 20120515 • FN overall project meting 20120521_23 • FN WS tariffs II 20120606 • FN Magdeburg 20121025_26 • FN Nov_Dec 2012	• FN January 2013 • FN February 2013 • FN March 2013

	(2008-)2010	2011	2012	2013
Interviews	/	**t1** • interview LiWa t1 expert G • interview LiWa t1 expert H • interview LiWa t1 expert I • interview LiWa t1 expert J • interview LiWa t1 expert K • interview LiWa t1 expert L • interview LiWa t1 expert M • interview LiWa t1 expert N	**t2** • interview LiWa t2 expert G • interview LiWa t2 expert H • interview LiWa t2 expert I • interview LiWa t2 expert L • interview LiWa t2 expert M • interview LiWa t2 expert O • interview LiWa t2 expert P • interview LiWa t2 expert M • interview LiWa t2 extern 1 • interview LiWa t2 extern 2 • interview LiWa t2 extern 3 • interview LiWa t2 extern 4 • interview LiWa t2 extern 5	**t3** • interview LiWa t3 expert I • interview LiWa t3 expert L • interview LiWa t3 expert N • interview LiWa t3 expert O

Annex I Participation of UBA experts during the different CIB&S phases (UBA)

Legend:

X= active participation

(X)= rather passive participation

No participation (grey shading)

*= together with expert A

	lable	Framing and Design	Selection of descriptors	Definition of alternative developments	Cross-impact assessment		Analysis and sampling of scenarios
scenario group	**Expert A**	X	X	X	X	X	X
	Expert B	X	X	(X)	(X)*		(X)
	Expert C	X	X	(X)	X	X	(X)
	Expert D	X	X	(X)	X		(X)
	Other UBA expert	X					
	Other UBA expert					X (partly)	(X)
	Other UBA expert					X (partly)	(X)
	Expert E	X	X	(X)	X		(X)
	Expert F				X	X	(X)
	Other UBA expert					X	
	Further UBA expert					X	
	Other UBA expert					X	
sc.- ex- perts	**Expert V**	X	X	X		X	X
	Expert W	X	X	X		X	X

Annex J (UBA) Original statements case UBA - translated into English in chapter 6

V 30	*„[…] da würde ich schon sagen, das ist ein Punkt, wo eben ganz besonders deutlich geworden ist, dass es ein Demonstrator ist und das Wichtige ist mal den Prozess ganz durchzuführen, dass jeder ein Gefühl hat, wie so was läuft und welche Art von Ergebnissen dann auch raus kommt, aber wo es jetzt nicht drauf ankommt, dass das Ergebnis auf Punkt und Komma das Bestmögliche ist."*
W 55	„Kein Mensch rechnet mit der obersten und mit der untersten [Variante]. D.h. du bist so abseits von allen."
DOC Minutes video conference 20101029	„Wohnfläche pro Kopf: ein zusätzliches Szenario mit möglichst großer Varianz wird von ZIRIUS, sofern möglich, noch ergänzt." „Ölpreis: für die Variante „hoch" wird ZIRIUS nach höheren Werten suchen, um noch eine deutlichere Varianz zu erzielen."
B 134	*„Wobei wir uns jetzt in unserem Vorgehen sehr stark auf die Ergebnisse gestützt haben, die wir durch andere Prognosen quasi ausgewertet haben und haben weniger selbst gedacht. Insofern haben wir uns da ein bisschen limitiert, aber dadurch, dass es für quantitative Modellarbeit eigentlich gedacht ist, ist es in dem Zusammenhang in Ordnung, in einem anderen Zusammenhang würde ich quasi schon die Prognosen auch verwenden, aber vielleicht auch noch mal selbst nachdenken."*
A 96	*„In diesem Anwendungsfall war die Methode außerdem leider nur eingeschränkt, da wir uns auch eine eher quantitative Logik beschränkt haben („hoch", „mittel", „tief"), das könnte viel interessanter sein, wenn man von echten Beschreibungen und qualitativen Überlegungen ausgeht.. Wenn man also eher einen weicheren Szenario-Ansatz gewählt hätte, hätte man sicher einen breiteren Raum zukünftiger Entwicklungen abgedeckt. Bei SAS ist das ja so, und dann hat man aber das Problem der Transformation…"*
W 102	*„Klar – die Zeit hat nicht gereicht. Im Antrag stand ja auch drin ein zweitätiger Workshop. Und dann hätte man das auch wirklich so machen müssen, wenn man am Anfang zehn gut ausgefüllte, ganze Matrizen gehabt hätten, dann hätte man sagen können „und wir reden über diese 50 Urteile. Die sind widersprüchlich". Und dann wäre das Ganze in einem Tag durch gewesen."*
V 31	*„Und das war dann praktisch immer sehr, sehr wertvoll, alles was da durchgesprochen wurde, da ist allen Beteiligten eigentlich noch viel mehr klar geworden. Und die Urteilsqualität in den Fällen, die durchgesprochen wurde, ist so deutlich besser geworden durch die Durchsprache, dass man dann hinterher schon sagen muss, es ist schon eine kräftige Lücke, dass so viele Felder nicht durchgesprochen worden sind. Man kann ja dann vermuten, dass dort die Urteilsqualität auch noch mal gemacht worden müsste. Vielleicht nicht so deutlich wie bei den identifizierten Problemfelder, ist ja kein Wunder, dass sich viel getan hat durch das Diskutieren, aber trotzdem denke ich, wäre die Matrix doch noch mal ein gutes Stück besser geworden, wenn man die Zeit gehabt hätte, über alles zu reden."*
A 83	*„Im Endeffekt steckt ja in den quantitativen Modellen auch die Kausalzusammenhänge drin und im Prinzip muss man die kennen, die muss man kennen, ob die Kopplung passt, muss man mit exogen, endogen ganz sorgfältig schauen, wo welche Faktoren wie verknüpft sind. Da schauen mehrere ‚Stielchen' aus so einem Modell heraus raus und da muss man schauen wo man ansetzt."*
V 118	*„[…] beim praktischen Ausüben müssen eigentlich alle Disziplinen erst mal über einen Abgrund springen."*
A 44	„Die Methode an und für sich ist auf den ersten Blick bestechend einfach. Sie ist sehr transparent und sie ist sehr klar."
F 34	*„Ich kann mir vorstellen, wenn man das öfter macht, dass man, wenn man mehr drin ist […] dann auch nicht mehr so durcheinander kommt, so was wirkt denn jetzt, was muss ich denn jetzt denken? Ist dies die Auswirkung, oder das die Auswirkung oder das. Das war halt für mich beim ersten Mal ziemlich schwierig."*
D 48	*„Im ersten Schritt fand ich es ziemlich einfach. Wenn man dann näher drüber nachdenkt,*

	dann wird es immer wieder schwierig. Man muss sich immer wieder die Frage stellen, ist das jetzt die richtige [Wirk-]Richtung, in die ich gerade denke. Dann wird es schon ein bisschen kompliziert. Aber es geht.“
F 34	*„Und dann mal zu überlegen, ist das ein direkter Einfluss oder ein indirekter Einfluss und diese Matrix zu überblicken […] Das ist an sich, was für mich ungewohnt war. Aber ich fand es verständlich worum es geht und so, aber sich das dann halt immer für jeden Faktor sich wieder neu vorzustellen, wie ist das jetzt…also… ist das jetzt indirekt oder direkt. Also war wirkt da eigentlich noch mit rein, also…war schon sehr aufwändig, wenn man das zum ersten Mal macht, sich da erst mal reinzudenken.“*
A 50	*„Also die <u>Einzelfrage</u> ist ja immer einfach, relativ vergleichsweise einfach, aber weil es eine Multiplikation ist, wie viele Einzelfragen ich mir stellen muss, also die Komplexität dieser Methode kommt aus einer anderen Ecke sagen wir es mal so.“*
A 44	*„Auch sich im internen Dialog immer wieder die richtigen Fragen zu stellen und auch immer wieder zurückzuführen auf eine Grundfrage und auch immer wieder <u>wach</u> und <u>bewusst</u> an die Verknüpfung ran zu gehen.“*
D 157	*„Man muss sich da schon konzentrieren drauf und noch mal drüber gehen, hat man es auch richtig gemacht? Es war nicht irgendwie so, dass man das ohne viel Hirnschmalz machen konnte, aber es ging. Wenn man sich konzentriert, dann geht das schon ganz gut.“*
V 33	*„Also ich glaube das ist dem einen oder anderen schon ein bisschen schwer gefallen. Das habe ich dann schon auch bei den ersten feedbacks gemerkt, ganz genau weiß ich es nicht mehr. So aus den Gesprächen, dann wenn man die Leute dann bei dem Workshop da gehabt hat. Und ich möchte auch sagen, aus dem Gefühl, dass das eine oder andere Urteil ein bisschen unsinnig zu sein schien, da würde ich schon sagen, da waren sich manche ein bisschen unsicher, wie sie es genau machen sollen.“*
W 215	*„Was natürlich <u>dauernd</u> das Problem war, dass <u>indirekt</u> gedacht wurde. Diese indirekten Einflussbezüge. Das finde ich persönlich auch <u>schwierig</u>. Die UBA Leute haben <u>sehr</u> oft indirekt gedacht.“*
C 54	*„Ich habe das Gefühl, manche Kollegen sind nicht ganz so weit gegangen, haben die Spielregeln nicht ganz verstanden und deshalb wussten sie auch nicht so recht, wie sie es machen sollten.“*
F 122	*„Also, am Ende die Szenarien, das passt mit dem und dem und dem zusammen irgendwie. Das waren doch die Ergebnisse. Die Logischen, so war es glaube ich nicht ausgedrückt, die wahrscheinlichsten Szenarien? Nein…[…].“* *HK: „Die konsistentesten.“*
F 128	*„Ach ja, genau konsistent. Also das fand ich schon gut, das da das rauskommt am Ende, wo man sehen kann, o.k. wenn ich das und das annehme, dann passt das und das und das zusammen…Und das man dann noch sieht, wie konsistent ist das und woran liegt's, das es nicht so konsistent ist und so.“*
C 41	„Und in die Auswertung bin ich nicht so tief eingestiegen, das habe ich mir halt angeschaut, wie das gemacht wurde und war aber schon ganz zufrieden, dass das jetzt schon deutlich den Szenarienraum eindampft. Insofern funktioniert es, das war ja die Hoffnung, dass man ein paar [gemeint: Kombinationen] auswählt.“
C 44	*„Die Auswertung, gut, ein Stück weit halt ist es dann eine Black-Box, bevor man wieder anfängt zu interpretieren. Da vertraue ich einfach drauf, dass das funktioniert und durch die Literatur, die es dazu gibt, auch gut genug belegbar ist, dass man da also in der Fachwelt mit auftreten kann. Und da finde ich, das kommt mir entgegen, dass man sich hier eine Methode auswählt, die doch irgendwie ganz gut begründet ist und auch sinnvoll erscheint.“*
B 99	*„Mir kommt es auf jeden Fall sehr plausibel vor, ich habe das jetzt nicht angezweifelt“.*
V 61	*„Mein Eindruck, was ich da mitgenommen habe, es ist grundsätzlich angekommen […].“*
V 61	*„[…] Was man da immer nicht weiß, ob jemand dieses Konsistenzprinzip tatsächlich nach-*

	vollzogen hat, überzeugend gefunden hat oder ob es ihm einfach reicht zu sehen, es wird irgendwie halbwegs sinnvoll gemacht und die Ergebnisse sind plausibel, dann glaube ich auch, dass das Konstruktionsprinzip vernünftig ist, das kann auch sein und wenn jemand sich selbst so definiert, dass er sagt, dass die Ergebnisse plausibel sind, dann muss ich das nicht unbedingt im Detail verstehen, dann ist das auch okay, dann reicht das für mich auch als Methodiker. Man muss ja nicht jeden Beteiligten zwingen. Das Ziel ist die Zufriedenheit. Es ist ja ein heuristisches Instrument und deshalb ist das Ziel einfach das Bedürfnis dessen, der damit arbeitet, herzustellen „jetzt ist er zu plausiblen Lösungen gelangt."
V 68:	*„Wenn sich jemand nicht mit technischen Details befasst und sich sagt, das wird schon vernünftig sein."*
V 112:	*„Ich glaube da ist für alle Disziplinen erst mal eine Zumutung."*
F 128	*"Also das fand ich schon gut, das da das rauskommt am Ende, wo man sehen kann, o.k. wenn ich das und das annehme, dann passt das und das und das zusammen…Und das man dann noch sieht, wie konsistent ist das und woran liegt's, das es nicht so konsistent ist*."
E 36	*„Ich würde mir nicht zutrauen, diese CIB über alle Prozessschritte alleine durchzuführen."*
E 39	*„Gerade wenn es darum geht, Konsistenzprüfung zwischen den einzelnen Faktoren und Szenarien, das wäre so eine Sache, wo ich sagen würde, weiß ich nicht ob das klappt, wenn man sich da im Alleingang irgendwie durchwurstelt."*
E 42	*„Das lief ja bei ihnen am Institut, ich habe es selbst nicht ausprobiert, wo ich nicht weiß, ob es das tatsächlich so problemlos gehen würde."*
FN publication 201101	*„Allerdings finden wir den Bericht schwer lesbar und teilweise nicht verständlich. So ist die Erläuterung des methodischen Ansatzes zu ungenau, um wirklich gut zu verstehen, wie vorgegangen wurde.[…] aktuell ist das ein Text für echte Spezialisten. […]"*
C 58	*„Wenn dann praktisch mit Hilfe einer solchen Matrix dokumentiert ist, was rein geht in die eigenen Modelle. Dann wird es auch transparenter."*
F 154	*„Ich fand das wirklich eine gute Methode sich darüber klar zu werden, was wirkt wie mit was zusammen und das mal zu verdeutlichen."*
F 140	*„[…] durch diese Matrix [wird] einem richtig deutlich gemacht wird, wo die Wechselbeziehungen intensiver sind und wo nicht so…."*
A 62	*„[…] wirkt sehr spröde und von daher ist es glaube ich nicht so intuitiv, nicht so <u>inspirierend</u>."*
A 65	*„Wenn man sich die Abschlussdokumentation anschaut und dann dort an diesen Teilnetzen, Visualisierung angehen, da erschließt sich auf einmal das Ganze noch mal ganz anders. Dann öffnet es noch mal, den Blick und die Verständlichkeit dafür. Also wenn man nur die Zahlen in der Matrix sieht, Kollege meint, sieht aus wie Käsekästchen, ist nicht so <u>erfassbar</u> als wenn Sie ein Bild daneben malen oder ein Bild da haben, also eine Visualisierung daneben haben."*
FN final workshop: 60	*„Kritisch äußerte er [expert A]: Wenn man nicht an der Diskussion beteiligt ist, ist sei die Matrix schwierig zu verstehen. Die Darstellung der einzelnen Faktoren, wie im Bericht, dagegen sei leicht zu verstehen."*
A 121	*„Trotz aller Dokumentation, d.h. selbst wenn ich jetzt hingehe wird kein Mensch, kein Außenstehender, der die Cross Impact Diskussionen nicht miterlebt hat, <u>keiner</u> wird die Matrix verstehen, wenn er sich die einfach nur anschaut. D.h. man kann sie <u>akzeptieren</u>, kann sagen, ich glaube euch und deswegen ist es aber wichtig, dass die Expertengruppe, die diese Matrix oder das Projekt erstellt hat, entsprechendes <u>Standing</u> hat"*
V 86	*„[…] Sagen wir mal so, das Angebot war ja da […] Also das denke ich von der Anlage her, vom Angebot her hätte es transparent sein können. […]."* *„[…] Und ich denke für viele war es vom Ablauf her auch transparent".* *„[…] Also für die Personen, die von Anfang an auch bei diesem Auftakt-Workshop dabei gewesen sind, denke ich, dass zumindest die Abläufe transparent gewesen […]."*

B 66:	*„Und die Cross-Impact Matrix selbst, dadurch dass Sie immer die Begründungen z.B. demonstriert haben, warum welche Bewertungen zustande kamen, das ist natürlich für die Nachvollziehbarkeit ganz toll gewesen."*
A 65	*„Wenn man sich die Abschlussdokumentation anschaut und dann dort an diesen Teilnetzen, Visualisierung angehen, da erschließt sich auf einmal das Ganze noch mal ganz anders. Dann öffnet es noch mal, den Blick und die Verständlichkeit dafür. Also wenn man nur die Zahlen in der Matrix sieht, Kollege meint, sieht aus wie Käsekästchen, ist nicht so erfassbar als wenn Sie ein Bild daneben malen oder ein Bild da haben, also eine Visualisierung daneben haben."*
E 60	*„Es war tatsächlich auch genau dieses strukturierte Vorgehen, was mir bei meinen eigenen Versuchen, Rahmendaten einzusammeln für meine Langfristszenarien im Vergleich gefehlt hat und dadurch habe ich gemerkt, das stärkt für mich auch deutlich das Vertrauen in die Zuverlässigkeit von Rahmendaten, wenn ich das Gefühl habe, es ist systematisch abgeprüft und in sich stimmig."*
W 174	*„so wird es[beim Faktor Demographie] überall gemacht. Es gibt zwei mittlere Pfade, die überall genommen in allem werden. Und wir hatten so einen in der Mitte, der quasi nirgends auftaucht. Und wahrscheinlich nur der ist konsistent mit allen anderen, weil dass wir auf die 100 Millionen zusteuern, ist Quatsch. Dass wir auf 60 Millionen runter fallen, ist auch Quatsch. D.h. da hätte man ein bisschen mehr Feintuning machen müssen."*
F74	*„Das kann ich mir vorstellen, dass man dann…dass man dann trotzdem, wo man wieder seine Vorurteile rausholt und sagt, nee, dass gehört nicht zusammen und dann gar nicht weiter darüber nachdenkt, das kann dann natürlich auch sein, wenn man dann so eine große Matrix vor sich hat, dann geht man trotzdem nur bewusst auf die Wechselwirkungen ein, die man eh schon im Hinterkopf hat."*
W 105	*„Und der Witz ist, dass dann z.B. vielleicht etwas aufgeklärt wurde oder ein Widerspruch aufgeklärt wurden, dadurch dass man diesen einen Faktor dann mal durchgemacht hat. Und das beim anderen Faktor aber nicht durchgemacht hat. Und ich dann immer wieder das Gefühl hatte, wenn man zu dem anderen noch mal systematischer rangekommen wäre, hätte man auch noch mal alle Urteile revidiert."*
W 87	*„"Und ich dachte dann „oh Gott, die haben das ja überhaupt nicht ausgeglichen (i.e. had not applied the standardization rule]– als ich dann die Ergebnisse gesehen habe. Ich war enttäuscht als ich die Matrizen [of the individual survey] gesehen habe. Weil ich fand, das war echt nicht so wirklich viel mit gearbeitet."*
W 293	*„Die Kreativität wurde im Prozess immer wieder abgewürgt."*
B 124	*„[…] Insofern denke ich mal, es geht eher um solche Sachen, ob mit systematischem Arbeiten, ob einem das liegt oder ob man sich ein bisschen wie an einer Kette fühlt."*
C 61	*„Die Projekte laufen ja nie alle synchron, sondern zeitversetzt und dann gibt es ein Folgeprojekt und da werden die Ergebnisse mit dem Vorherigen verglichen. Da müsste man sich halt dann tatsächlich einmal drauf festlegen [auf die Methode] und ein paar Jahre auch durchhalten, und zwar in allen betroffenen Einheiten."*
V 133	*„Also aus Szenario Perspektive fehlen für mich noch die eher weichen Faktoren. Dadurch, dass man sich darauf beschränkt hat, nur Rahmenannahmen zu machen für Modelle, ohne quasi vermittelte Dinge zu erklären, sind sie für mich jetzt unvollständig. Sie sind für den begrenzten Raum in dem sie erstellt worden sind gelungen, relativ sinnvoll, aber nur mit dieser Einschränkung."*
A 96	*„In diesem Anwendungsfall war die Methode außerdem leider nur eingeschränkt, da wir uns auch eine eher quantitative Logik beschränkt haben („hoch", „mittel", „tief"), das könnte viel interessanter sein, wenn man von echten Beschreibungen und qualitativen Überlegungen ausgeht.. Wenn man also eher einen weicheren Szenario-Ansatz gewählt hätte, hätte man sicher einen breiteren Raum zukünftiger Entwicklungen abgedeckt."*
A 18	*„Mein Problem bei der Story and Simulation Methode ist, ähnlich wie beim Szenario-Planning, aber da weniger, dass es unglaublich schlecht nachzuvollziehen ist, wie es zu dieser Story gekommen ist.[…] Die Auswahl der Schlüsselfaktoren [.] ist nach dem was ich bisher davon kenne wenig transparent, schlecht zu dokumentieren und häufig im Dienste*

	des Modells. Also dass es dann rückgekoppelt wird, dass die Schlüsselfaktoren sich durch das Modell sozusagen determiniert werden und daraus ist das natürlich ein sehr eingeschränktes Bild in die Zukunft."
E 83	*„Also für mich ist das wichtigste Ergebnis eine Methode kennengelernt zu haben, wie ich auf strukturierte Art und Weise auf einen plausiblen Satz von Rahmendaten kommen kann. Das ist das zentrale Ergebnis dieses Projektes für mich."*
A 24	*„Deswegen sind wir ja auch zu dem Projekt gekommen. Da geht es im Wesentlichen auch um Konsistenz und Plausibilität und das Zusammenwirken der Faktoren. Auch die Exogenen sind sicherlich irgendwie gekoppelt und nicht alleine. Und von daher sollte man es dann durchaus wagen, einen Schritt Komplexität sozusagen drauf zu legen und nicht nur das Eindimensionale, sich mit einzelnen Rahmendaten oder Annahmen zu beschäftigen."*

Annex K Original statements case Lima Water - translated into English in chapter 7 (Lima Water)

L t2 145 et sq.	*„[…] aber was <u>mehr</u> die Deskriptoren Essays verändert hat oder beeinflusst hat, ist die Diskussion in der CIB Matrix. Wir hatten ja am Anfang versucht oder gesagt, wir brauchen zuerst die Deskriptoren Essays und Definition und die nehmen wir so, wie sie beschrieben werden, im Lauf des Prozesses werden dann die Einflüsse bewertet. Aber es hat sich eher gezeigt, dass es eher anders rum war, also bei der Diskussion der Einflüsse man gesagt hat, den Deskriptoren muss man eigentlich anders fassen, weil so wie er im Moment am Anfang beschrieben wurde, ist er nicht sinnvoll, ihn so zu verwenden. HK: D.h. das war der größere Einfluss [im Vergleich mit der Quantifizierung] eigentlich auf die Deskriptoren? CIB-scenario expert L t2: Ja, würde ich schon sagen.“*
FN March 2012: 386 et sq.	*„Die Storylines sind ins Spanische übersetzt worden und in den letzten Wochen von der Szenariogruppe bearbeitet worden […]. Scenario group member P, die Nachfolgerin von K, hat, obwohl (HK: oder ggf. sogar weil?) sie nicht am Szenariokonstruktionsprozess beteiligt war, 1-seitige Kurzfassungen der Szenarien, A, B (B1 + B2), C und D geschrieben. Diese waren Grundlage der Arbeitsgruppen am RT II (gemeinsam mit dem CIB Szenario tableau).“*
DOC Final descriptor essay on tariffs	“No se analiza la tarifa que se cobra por el suministro de agua por camiones cisterna.”
L t3 41	*„<u>Veränderungen der Zeitreihen, die hat ja damit zu tun, welches zunächst das Basisjahr ist. Da Tritt die Problematik auf, dass manche, v.a. SEDAPAL, sich nicht mit den alten, schlechteren Zahlen befassen möchten, die sind ja schon Geschichte</u>**…** Je länger der Prozess dauert, desto mehr neue Zahlen kommen. Die Modellierer waren, zum Beispiel, sehr offen für neue Zahlen. Das Problem war dabei, dass man immer wieder auf neue Zahlen warten musste. Da hätte man vielleicht einfach stringenter sein müssen, „zack Basisjahr ist 2011, dabei bleiben wir…“. Aber die Modellierer waren da eher offen, vor allem wenn von SEDAPAL was Neues kam. Das war dann auch Diskussionspunkt zwischen uns.“* (my emphasis)
O t3 43	*„Was außerdem dazukommt, wir hatten bisher gesagt, dass wir bis 2013 entweder konstante Werte annehmen oder eine einheitliche Entwicklung für alle Deskriptoren. Jedoch haben wir jetzt für 2013 ganz aktuelle Werte erhalten haben, also ANF mit 30% statt 34%. Wie geht man damit um. Ich habe das jetzt für 2013 auf 30% gesetzt und die Zeitreihen entsprechend verschoben, sodass der Anstieg von 30% auf 40% bzw. der Abstieg von 30% auf 25% erfolgt. Zugleich aber müsste möchte ich für 2011 die alten Werte für 34% simulieren, da ich immer noch den Abgleich der Ergebnisse von 2011 mit dem Annuario 2011 von SEDAPAL mache um eine gewisse Referenz zu erhalten, und ein gewisses Grundvertrauen ins Model zu bekommen. Mit Expert L (t3) habe ich vereinbart, dass wir doch den Werten des Jahres 2011 ausgehen. Von dem ausgehend, auf die Entwerte de Zeitreihe des Jahres 2040 zugehen, und uns nicht von der leichten Verbesserung von 2013 irritieren lassen, sondern bei 2011 als Basisjahr bleiben, als das Jahr zu dem wir die kompletten Informationen haben. Das wär aber was, wo man beim nächsten Mal grundsätzlich festlegen sollte, wie man mit sowas umgeht.“*
L t3 38	*„Eine andere Sache, die auch mit der Quantifizierung zu tun hat, sind die Grünflächen. Wir haben eine andere Anzahl gemessen als die offiziellen Zahlen. Und das finde ich auch erstmal unproblematisch, im Prinzip.“*
L t3 39	*„Hier, zum Beispiel, wird deutlich dass auch politische Faktoren mit einbezogen werden. Lima nutzt die 2,4 m2/Person um zu fordern, dass mehr Grünflächen geschaffen werden. Und da sind die vom LiWa Projekt wissenschaftlich gemessenen von einem Status quo von 4,0 m2/Person möglicherweise politisch unerwünscht, da das ja so aussieht, als stünde Lima gar nicht so schlecht da. […] Das haben wir vielleicht bei der Quantifizierung unterschätzt, wie politisch sensibel diese Zahlen werden könnten.“*
FN Nov_Dec	*„Am Montag war noch LT-Schulung. Wir haben dort das Modell und die Werte bekom-*

2012: 66	*men, die für die Szenario-Simulation verwendet wurden. Dabei fiel mir auf, dass er die Werte für Armut in Szenario A-B-C mit denen von D vertauscht hat (ich hoffe nicht für die Simulation des RT4). Es kam auch Kritik an den Werten für Armut (NSE D+E) insgesamt, die seien zu hoch gegriffen. Die leidige Diskussion hatten wir ja schon... Aber je nach Werten bekommt man natürlich andere Simulationsergebnisse. Es wäre also schon wichtig, die Daten nochmal zu prüfen (oder prüfen zu lassen). Wichtig ist, die Datenquelle zu haben; dazu konnte Expert O nichts sagen. Expert M war die komplette letzte Woche krank und hat leider nichts mitbekommen.“*
O t3 40, 41	*„Es wurde stattdessen angenommen, dass sie sich entsprechen dem Verhältnis von Schichten D-E zu dem Rest der Schichten verschieben. Deshalb habe ich dann die Schichten A, B und C separat betrachtet, und die Situation aus methodisch-didaktischen Gründen besser in Richtung Dramatik zu biegen. Deshalb habe ich die Reichen reicher werden lassen, was zu mehr Wasserverbrauch führt und insgesamt mehr Wassernachfrage. Das war meine Hauptmotivation, ehrlich gesagt. Lies sich dann ohne großen Aufwand machen.“*
O t3 45	*„Ein weiteres Problem war, dass die Ergebnisse uns teilweise nicht dramatisch genug waren. Also haben wir versucht es do hinzudrehen dass die Ergebnisse etwas dramatischer wurden. Deshalb ging das mit der vollständigen Szenariensimulation dann auch nicht so schnell wie ursprünglich erhofft. Weil Ergebnisse auch nicht so waren, wie wir sie wünschen würden.“*
O t3 43	*“Ich denke das man so einen Prozess in Zukunft doch mehr streamlinen müsste, da haben wir doch alle immer wieder ganz schön drunter gelitten.“*
O t3 31	*„Interessant auch, aus meiner Sicht, nach den möglichen Bewertungskriterien hatte ich schon vor mindestens 2 Jahren gefragt, keine Bekommen und mir dann selbst welche ausgedacht. Dann kam in den letzten Wochen doch noch einiges zu ‚oferta-demanda‘ Kriterien…Meine Anregung für das nächste Mal wäre, die Kriteriendefinition klarer und früher zu erhalten. [...] Bisschen unklar war für mich die Trennung bzw. Zusammenhang zwischen Szenarien und Maßnahmen. Da würde ich für das nächste Mal vorschlagen, dass auch schon in der Szenariogruppe in Peru schon genauer und schärfer zu trennen, was zu was gehört, also was ist Szenario, was ist Maßnahme. Einige Maßnahmen stecken ja in den Szenarien dann schon drin…Was dann für mich bei der Simulation schwierig war, dass ich, überspitzt formuliert, manche Maßnahmen nicht simulieren durfte, weil sie mit dem Szenario inkonsistent sind. Wiederum erschienen mir eure Ansagen, oder die von Expert L in sich inkonsistent. Neulich, am 6. März hatten wir eine Kette von 'medidas' durchsimuliert simuliert und Expert L meinte daraufhin, dass diese Maßnahme im Szenario A gar nicht funktionieren. Obwohl dieselbe Maßnahmen – Kette im November zuvor von uns allen am runden Tisch simuliert wurde, und da ging das offenbar…mir ist das ja, bin ich emotionslos, aber da muss man klarer sein, was ist konsistent, was ist erlaubt, was nicht. […].“*
G t1 55	*“[...] uno de los problemas más frecuentes que hubo en la evaluación de los impactos era confundir a veces si este desc impactaba al otro o el otro impactaba al primero. Ósea es una cose difícil a veces, especialmente cuando ya se avanza mucho en el tiempo de la discusión, parece que el cerebro ya se cansa un poco."*
G t1 71	*“Por supuesto que no es fácil. Uno intenta, supongo que ustedes están intentando que sea lo más fácil posible, pero como hay tantos factores, tantos descriptores, termina siendo un poco complejo [...].”*
J t1 39	*“En general, la metodología fue muy participativa, interesante <u>y tediosa por lo de los numeritos</u>.”*
H t2 48	*“En el grupo hemos trabajado el tema de los guiones cortos. Evidentemente en este guion no se puede poner todos los cálculos que habia atras. Pero si, en general fueron claros y entendibles. Al menos, si habia alta crecimiento de poblacion, gobernancia fuerte o no...”*
G t2 39	*“[...] Cuando tu no participas en un proceso, podrías creer que los escenarios eran fabricadod el día anterior solo.”*
G t1 58	*“Pero se nos dijo que el programa establecía que tenía que ser una sumatoria de cero. Entonces eso fue difícil entenderlo y puede haber distorsionado algunas veces el valor asignado.”*

K t1 108	*"un corset tan pesado"*
K t1 75	*"Los numeritos, hemos perdido mucho, mucho contenido de la discusión, inclusive muchas negociaciones que se han hecho allí."*
L t3 37	*„In den Tabellen spiegelt sich die Problematik in den kurzen Überschriften wieder, die nicht die eigentlichen Verständnisse und Definitionen wiederspiegeln, hinter denen ja auch vielfältige nicht triviale Entscheidungen stehen, die irgendwer ja mal treffen musste. Das haben wir vielleicht erstmal unter uns gemacht, wenn man das dann aber präsentiert, dann wird einem das erstmal, zum Teil, um die Ohren gehauen, so wie gestern. Vielleicht haben wir es auch nicht immer sooo gut parat, was wir ‚eigentlich' in der Langversion meinen, wenn wir nur die kurzen Schlagworttitel wie „pobreza" verwenden…"*
O t3 94	*„[…] Letztendlich spielen die extra definierten Zeitreihen eine Rolle. Das andere ist, für meinen Teil der Arbeit, nicht egal, aber sicher nicht direkt relevant. Ich muss einfach wissen, wie sieht die numerische Zeitreihe aussieht. Das ist das Wichtigste für mich. Die Prosa drum rum ist für mich nicht so wichtig[…]."*
M t2 38	*„Egal, wer das hier schreibt wird dann immer wieder ein Fokus auf <u>einen</u> der Deskriptoren sein oder vielleicht nicht auf einen Deskriptor, aber dann halt auf meinen Fachbereich. Was das Ganze auch* wieder verfälscht. Eventuell wäre es lesbarer gewesen, aber ich könnte mir vorstellen, dass es auch einseitiger gewesen wäre. Also von daher ich glaube, es ist gar nicht schlecht ein Gerüst von außen zu bekommen, aber *es ist glaube ich auch nicht möglich, dass das von außen gestellte Gerüst so von der Gruppe aufgenommen wird und unkritisiert weiterverwendet wird."*
O t3 92	*„Könntest Du mir noch mal ein Beispiel geben für so eine Inkonsistenz? Ich hab die jetzt nicht mehr so parat…"*
O t3 94	*„Worauf man achten muss, ist dass es nicht zu inkonsistent wird, sondern irgendwie zusammenpasst zwischen Text und Simulation. Vertrauensverlust wäre nämlich die Folge davon. […]"* *„[…] Letztendlich spielen die extra definierten Zeitreihen eine Rolle. Das andere ist, für meinen Teil der Arbeit, nicht egal, aber sicher nicht direkt relevant. Ich muss einfach wissen, wie sieht die numerische Zeitreihe aussieht. Das ist das Wichtigste für mich. Die Prosa drum rum ist für mich nicht so wichtig. <u>Liegt in der Natur der Sache, ich muss ja was ins quantitative Modell reintun, und simulieren</u>"* *„[…] Manchmal Stand im Prosatext Dinge ausgeschmückt, was eigentlich gar nicht zur Zeitreihe passt bzw. in der Zeitreihe so gar nicht steht. Weiß ich nicht mehr genau wo… z. b. die El Ninos… Wie das da reinkam, wie das aus den Zeitreihen gedeutet wurde, weiß ich nicht…"*
L t3 45	*„Auf alle Fälle gab es eine Veränderung der Wahrnehmung möglicher extremer/ pessimistischer Deskriptorausprägungen, wenn man die Diskussion von gestern wahrnimmt, dann sieht sie man dass nun angenommen wird, dass die Bevölkerung nicht mehr so stark steigt. Bei der Armut war der gleiche Trend zu verzeichnen. Ich denke dass seit Fujimoris Abdanken, alle 3 neue Regierungen diese Wirtschaftspolitik fortgeführt wurde, also ausländische Investitionen, Sozialprogramme, usw. Vielleicht soll den Leuten beigebracht werden, dass diese Zeit auch bald vorbei sein könnte. Nur weil die letzten 10 Jahre dies der Trend war, heißt das nicht, dass es die nächsten 30 Jahre so weitergeht. Es kommt darauf an wer die Stadt in Zukunft führen wird.[…]. Man müsste die Leute aus der Sichtweise rausbringen, in Richtung Prognose zu denken und alles optimistisch zu sehen. Denn wir denken bis 2040, da kann einiges passieren. Das ist vielleicht nicht wünschbar aber möglich. Wenn das geschafft ist, dann hat man schon einen großen Schritt gemacht. Aber es gibt auch die Leute die dann sagen, die Armut nimmt seit 20Jahren ab, das kann sich nicht mehr drehen."*
L t3 35	*„[…] Zusätzlich kamen da die Schwierigkeit dazu, dass sich keiner traut, dazu Hochrechnungen oder Szenarien zu erstellen, wie sich die Schichten bis 2040 entwickeln."*

Annex L Final CIB matrix "Germany 2030" (UBA)

Source: Weimer-Jehle/ Wassermann/ Kosow 2011

Cross-Impact Analyse UBA - Deutschland 2030	A. Bev			B.WF		C. BIP				D. Öl			E. PEV			F.TMR		G. PVL			H. GVL			I. N-Üb			J. Klima		
	a1 leichter Rückgang	a2 mod. Rückgang	a3 starker Rückgang	b1 starker Anstieg	b2 geringer Anstieg	c1 starker Anstieg	c2 mittlerer Anstieg	c3 schwacher Anstieg	c4 volatil	d1 starker Anstieg	d2 mittlerer Anstieg	d3 etwa konstant	e1 leichter Rückgang	e2 mittlerer Rückgang	e3 starker Rückgang	f1 ansteigender Verbr.	f2 etwa stabil	g1 deutlicher Anstieg	g2 moderater Anstieg	g3 leichter Rückgang	h1 sehr starker Anstieg	h2 starker Anstieg	h3 mod. Anstieg + Verl.	i1 Stagnation	i2 Business as usual	i3 Verstärkter Rückgang	j1 deutlich feuchter	j2 moderat wärmer	j3 deutlich wärmer
A. Bevölkerungsentwicklung																													
a1 leichter Rückgang auf ca. 81 Mio				1	1	0	1	1	0	0	0	0	2	1	-1	1	0	-1	0	1	0	0	1	1	1	0	0	0	0
a2 moderater Rückgang auf ca. 79 Mio				1	1	-1	1	1	0	0	0	0	2	2	0	0	0	-2	-1	1	-1	0	1	1	1	1	0	0	0
a3 starker Rückgang auf ca. 76.6 Mio				2	1	-2	-1	1	0	0	0	0	1	2	2	-1	0	-3	-1	2	-1	-1	1	0	1	2	0	0	0
B. Wohnfläche pro Kopf																													
b1 starker Anstieg auf ca. 50.4 qm	0	0	0			0	0	0	0	0	0	0	3	1	-2	2	0	1	0	-1	0	0	0	0	0	0	0	0	0
b2 geringer Anstieg auf ca. 44.2 qm	0	0	0			0	0	0	0	0	0	0	-1	1	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0
C. BIP																													
c1 starker Anstieg auf ca. 3509 G€ (1.6%/a)	1	0	-1	2	-1					0	0	0	2	-1	-3	2	-2	2	1	-2	3	2	-1	1	0	0	0	0	0
c2 mittlerer Anstieg auf ca. 3120 G€ (1.2%/a)	0	0	0	1	0					0	0	0	1	0	-1	1	-1	1	1	-1	2	1	0	0	1	0	0	0	0
c3 schwacher Anstieg auf ca. 2830 G€ (0.8%/a)	-1	0	1	0	1					0	0	0	-1	0	1	0	1	0	1	1	-1	1	1	0	1	1	0	0	0
c4 geringes und stark volatiles Wachstum	-2	0	2	-1	2					0	0	0	-1	0	0	0	1	-1	0	1	-2	0	0	1	1	0	0	0	0
D. Ölpreis																													
d1 starker Anstieg auf ca. 125 $/b	0	0	0	-2	2	-3	-2	-2	2				-1	1	2	1	-1	-2	-1	1	-2	-1	0	0	0	1	0	0	0
d2 mittlerer Anstieg auf ca. 91 $/b	0	0	0	-1	1	-2	-1	-1	2				0	1	0	0	0	-1	0	1	-1	-1	0	0	1	0	0	0	0
d3 etwa konstant bei ca. 67 $/b	0	0	0	0	0	2	2	2	1				2	0	-2	0	0	1	1	0	1	1	1	1	1	0	0	0	0
E. Primärenergieverbrauch																													
e1 leichter Rückgang auf ca. 13400 PJ	0	0	0	0	0	0	0	0	0	0	0	0				-1	1	0	0	0	1	1	0	0	0	0	1	1	2
e2 mittlerer Rückgang auf ca. 11000 PJ	0	0	0	0	0	0	0	0	0	0	0	0				-2	2	0	0	0	1	1	1	0	0	0	0	0	0
e3 starker Rückgang auf ca. 7700 PJ	0	0	0	0	0	0	0	0	0	0	0	0				-3	3	0	0	0	0	0	1	0	0	0	0	0	-1
F. Totaler Materialverbrauch																													
f1 ansteigender Verbrauch auf ca. 7200 Mt	0	0	0	0	0	-1	0	0	1	0	0	0	0	-1	-1			0	0	0	1	1	0	0	0	0	0	0	0
f2 etwa stabil bei ca. 6400 Mt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1			0	0	0	0	1	1	0	0	0	0	0	0
G. Personenverkehrsleistung																													
g1 deutlicher Anstieg um ca. 32%	0	0	0	0	0	1	1	1	0	0	0	0	0	-1	-1	1	-1				0	0	0	0	0	0	0	0	0
g2 moderater Anstieg um ca. 10%	0	0	0	0	0	1	1	1	0	0	0	0	0	0	-1	0	0				0	0	0	0	0	0	0	0	0
g3 leichter Rückgang um ca. 5%	0	0	0	0	0	-1	0	0	0	0	0	0	1	1	1	0	0				0	0	0	0	0	0	0	0	0
H. Güterverkehrsleistung																													
h1 sehr starker Anstieg um ca. 69%	0	0	0	0	0	2	1	0	0	0	0	0	0	-1	-2	2	-2	0	0	0				0	0	0	0	0	0
h2 starker Anstieg um ca. 53%	0	0	0	0	0	1	1	0	0	0	0	0	0	0	-1	1	-1	0	0	0				0	0	0	0	0	0
h3 moderater Anstieg um ca. 34% + Verlagerung	0	0	0	0	0	0	1	1	0	0	0	0	-1	0	0	0	0	0	0	0				0	0	0	0	0	0
I. Stickstoffüberschuss Landwirtschaft																													
i1 Stagnation	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-1	0	0	0	0	0	0	0	0				1	1	2
i2 Business as usual (ca. -20%)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0				0	0	0
i3 Verstärkter Rückgang (ca. -30%)	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	1	0	0	0	0	0	-1	0	1				0	0	-1
J. Klimaänderung																													
j1 kaum wärmer - deutlich feuchter	0	0	0	0	0	-1	0	0	1	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0			
j2 moderat wärmer - kaum feuchter	0	0	0	0	0	-1	-1	0	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0			
j3 deutlich wärmer - kaum feuchter	1	0	-1	0	0	-1	-1	0	2	0	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0			

Annex M Characteristics of the interviewees (UBA)

The following table sums up what the interviewees told me about their prior knowledge and experience with qualitative and quantitative scenario techniques, about their familiarity with systems thinking and whether they have a preference for systematic approaches. To better protect their anonymity, their disciplinary background is not given.

	Familiarity with qualitative scenario analysis*	Familiarity with quantitative scenario analysis*	Familiarity with systems thinking	Preference for systematic approaches
UBA expert A	+ Yes (A 18)	(+) Yes, but rather as a passive recipient user of model results (A 9).	Yes, by disciplinary training (A 157)	Not evident, rather considers systematic and creative aspects as as necessary to construct good scenarios (A 18).
UBA expert B	+ Own experience (B 8)	(+) Only little own experience, rather observation of work at UBA, rather skeptical and critical towards it (B 8).	/	Yes (B 124) Likes systematic appraoches.
UBA Expert C	- No (C 8)	+ Yes, through work with environmental impact assessments (C 8).	Yes. Energy systems analysis (C 8)	Yes, prefers when he can objectively calculate something. And he liked that he can work as systematically as he is used to (C 50).
UBA expert D	- No (D 16)	(+) Yes, but rather passive as 'recipient' user (D 10).	/	Yes, and for quantitative approaches (D 19)
UBA expert E	(+) Rather theoretical (E 8)	+ Through work at UBA (E 20)		Yes (B 60)
UBA expert F	- Newcomer (F 8)	(+) Recipient user (F 8)	Yes and he really likes it, too (F 176)	Yes (F 38)
Scenario expert W	Some (W 89). Considers himself a lay person (W 204).	No, became a recipient user of energy scenarios through the project (W 39).	No (W 228)	Stresses rather need for good workshop organization and facilitation (e. g. W 237). Pleads for more holistic perspective instead of detailed and systematic: (W 184)
Scenario expert V	Yes	Yes	Yes	Yes

* Familiarity with qualitative and quantitative scenario approaches: "+"= yes; "(+)"= some experience or experience as a recipient user; "-"= no

Annex N Comparison of judgments in mean matrix and final matrix (UBA)

See DOC CIB matrices over time.

Cells	**Mean matrix (n= 754 judgment cells in total)**	**% of all cells**	**% of non-0 cells**	**Final matrix (n= 754 judgment cells in total)**	**% of all cells cells**	**% of non-O cells**
3	*2*			*4*		
2	*33*			*33*		
1	*191*			*108*		
0	*453*			*529*		
-1	*59*			*60*		
-2	*14*			*16*		
-3	*2*			*4*		
Sum zero	*453*	*60*		*529*	*70*	
Sum positive	*226*	*30*	*75*	*145*	*19*	*64*
Sum negative	*75*	*10*	*25*	*80*	*11*	*36*
Sum non-zero	*301*	*40*	*100*	*225*	*30*	*100*
Overall matrix sum (if stand-ardization ap-plied = 0)	**+ 171**			**+ 87**		

Annex O UBA experts' difficulties during the individual survey (UBA)

In the matrices, the experts have marked uncertain assessments and have commented some of their judgements (see summary table below). Most comments (n= 11 out of n= 15) either contain justifications and reasoning on establishing second order effects and interactions through intermediary variables that are *not* considered as descriptors of the matrix, as e. g. lifestyles, prosperity, meat consumption, unemployment rate and income level, e. g. Or, they contain reasoning on second order effects through factors that *are* considered by other factors of the matrix (e. g. with regard to energy use or living space per capita). The remaining comments mainly refer to uncertainties with regard to the future existence of impacts, their continuity and their linearity.

Summary: Number of uncertain and commented judgment groups during individual survey (cf. DOC CIB matrices over time).

Parts of the matrix filled	Expert	Number of uncertainties	Number of comments	Issues
Entire matrix	E	4	7	Effect is indirect through intermediary **not** considered in the matrix: • prosperity and meat consumption (x 2) • efficiency investments (x 2) • unemployment rate and income level Effectis indirect through intermediary considered in the matrix: • Primary energy consumption (x 2) Uncertainty on future continuitiy of interrelation (if in a structural turnaround, renewables become dominant) Uncertainty, if there is an impact of one development onto another – or if the development is not strong enough to impact.
	A	3	1	Effect is indirect through intermediary: • lifestyles & meat consumption (not considered in the matrix) • big appartments (considered in the matrix)
	D	7	3	Indicator TMR not appropriate Very weak impact of Germany on global developments (Direction of impact confused)
Single issue related parts of the matrix only	F	/	2	Effect indirect through intermediary **not** considered in the matrix: • loss of atractivity of overcrowded roads
	C	3	2	Effect indirect through intermediary **not** considered in the matrix: • Prosperity and meat consumption Relation non linear (GDP and meat consumption)

The difficulties concerning indirect effects might have been linked to the rather *quantitative* definition of descriptors and to the lack of *qualitative and intermediary* descriptors, i.e. mediating variables that have not been included explicitly into the CIB impact network. This lack also was recognized by ZIRIUS during the final workshop, when the recommendation was formulated to add other factors beyond those that are directly modeling relevant. These might also contain 'soft' social factors as values, lifesyles etc, that can be considered the genuine drivers behind the dynamic of the modeling relevant factors (see DOC PPT final workshop, slide 29).This view was shared during the discussion in the final workshop (see FN final presentation: 87).

Annex P Factors for understanding CIB (UBA)

The evidence suggests that the understanding of CIB is influenced by several factors. First of all, the more **time** is invested to explain and to comprehend CIB, the better it is understood (cf. e. g. V 89, V 145). Also, the perceived understanding of CIB slightly varied with the **continuity of participation** during the process, see the following table.

Perceived understanding of CIB by number of process steps followed (UBA)

		Perceived understanding of CIB#		
		++	+	+/-
Number of process steps followed	5		A, C	
	4		D	E
	3	B		F

Subjective ease of understanding: "+ +"= easy without difficulties, "+"= overall rather easy; "+/-"= understandable but with several difficulties in the practice

Prior experience with scenario techniques is perceived as an influencing factor, too (F 34, B 69, W 134). Considered systematically, experience or missing experience with (qualitative or quantitative) scenario approaches seems to have an effect on the subjective ease of understanding: the more experience with qualitative and/or quantitative scenario approaches, the higher the perceived understanding of CIB, see the following table.

Perceived understanding of CIB by experience with scenario approaches (UBA)

	Qualitative	**Quantitative**	**Perceived understanding of CIB #**		
			++	+	+/-
Experiences with scenario approaches*	+	(+)	B	A	
	-	+		C, D	
	(+)	(+)			E
	-	(+)			F

Subjective ease of understanding CIB: + + easy without difficulties, + overall rather easy; +/- understandable but with several difficulties in the practice.
* Familiarity with qualitative and quantitative scenario approaches assessed "+"= yes; "(+)"= some experience or experience as' recipient user'; "-"= no experience

With regard to the influence of the disciplinary background, evidence is surprising. Scenario expert V (V 109) reports that generally, CIB is easier to understand for people coming from the natural sciences and engineering than for those coming from the humanities and the social sciences. But considering the *perceived* understanding of CIB together with the disciplinary background of the individual experts shows that this impression cannot be confirmed on the basis of the available evidence. In the UBA case, the (subjective) understanding of CIB does not co-vary with the disciplinary background of the participants.

Annex Q Internal actors: Roles, disciplines and organization of the scenario construction process (Lima Water)

	Type of actor	Disciplinary background	Role in the scenario process	Number	Organization of work
CIB scenario experts *(including myself as the 'combination persion')*	Researcher	Physics Social sciences Economics engineering	Organizing and facilitating qualitative scenario construction, matching and construction of combined results.	n= 4 Including the project manager Peru. n= 2-3 working constantly on the project.	Split equally between two scenario experts in Peru and two scenario experts in Stuttgart.
Scenario group	Experts and/or stakeholders representing all Peruvian project partners	Social sciences (Water) engineering Architecture and planning	Qualitative scenario construction with CIB.	n= 7-10	Ca. monthly scenario and expert workshops in Lima, facilitated by the scenario experts.
Modelers	researcher	Mathematics Water engineering Informatics	Eliciting knowledge of the system from project partners. Model building and simulation.	n= 3 internal and n= 2 external modelers; including the overall coordinator of the LiWa project.	Working mainly in Germany, plus extensive field trips to Lima for data collection, refinement, presentation and discussion of LiWatool

Annex R Central CIB matrices and scenario samples (Lima Water)

Type	**CIB matrix (No. 1-No. 9))**				**Descriptor essays**
Central version	No. 1	No 4.	No. 6	No. 9	Last version 2013
Date of production	10/2009	07/2010	05/2011	03/2012	From 2009-2013
Language	German	German	Spanish	Spanish	Spanish
Main authors	Scenario experts	Scenario experts	Scenario group	Scenario group	Scenario experts, issue experts
Target group	Internal project document	Matrix underlying scenarios presented in milestone report	Internal project document	Matrix underlying scenarios presented to scenario group (autumn 2011) and to external stakeholders in Lima (spring 2012)	Internal project documentation
Scenario sample (scenario tables)	/	N= 6 scenarios	/	V1: n= 16 (autumn 2011) (Annex CC) V2: n= 8 (March 2012) (Annex DD) V3: n= 7 (Mai 2013) (Annex EE)	/
Logic of the sample	/	2 *families* with 3 *variants* each	/	Four *families* with internal *variants*	/

Annex S Official short description of the raw CIB scenarios (Lima Water)

Source: http://www.lima-water.de/en/pp2.html

"**Scenario A: Climate stress meets governance disaster**

The water supply of Lima and Callao, in the year 2040, is under pressure due to the population growth, the city's horizontal and vertical enlargement, the difficult socio-economic situation, the deficits in water infrastructure and especially because of weak governance structures. This pressure grew progressively due to climate change effects during the last years, independently of the direction of the last one, either with clearly diminishing or increasing rainfall in the upper watershed.

Scenario B: The tragedy of isolated measures
Scenario B is very similar to Scenario A. The urban population increased during the last decades, the city continued the same tendency growing horizontal and vertically and with the dynamic of occupying the valleys. Even though the governance structures are very insufficient as in Scenario A, this scenario may count on some actors taking initiative, acting with the objective of improving the water system of the city and ensuring the water supply of Lima and Callao. In the variation B1 the management of the river watersheds comes out to work integrating different institutions in a participative way. In the variation B2 a private water company tried improving the overall situation of water supply. In both cases the actors act isolated and their measures are limited to certain areas of the water system.

Scenario C: The opportunities of mesoscale actors
In Scenario C the isolated acting actors of the mesoscale (meaning the level situated between central government and local entities) in the Scenario B (the integrated river watershed management and the private water company) are to be found together and working in a concerted way. Even though the population grew during the last decades and the city is maintaining its expansion tendency in a horizontal and vertical way; and also taking into account that Lima and Callao are suffering a serious climate stress and that general political and socio economic conditions are not more promising than in the Scenarios A and B, the concerted work of these two actors could achieve better results for Lima and Callao's water sector than the simple sum of their isolated activities.

Scenario D: Climate resilience by governance
The water supply of Lima and Callao in 2040 is relatively independent from climate change effects, thanks to strong governance structures on all levels (local, regional and national), that fostered the coordination, concertation and planning as key actions. Also because public policies which benefit inclusion, employment and are oriented towards poverty alleviation have been developed and promoted in the last decades. The city counts with a coordinated municipal development plan that incorporates adaptation strategies for the city favoring stable socioeconomic conditions and consolidated water infrastructure."

Annex T Two central versions of the storylines (Lima Water)

Type	Long version	Short version before (*and after*) Round Table
DOC	LiWa Storylines _long first comments 20120112	LiWa Storylines_short 20120314
Date of production	December 2011 - January 2012	February -March 2012
Language	German (Later translation into Spanish and English)	Spanish
Main authors	Scenario experts	New scenario group member expert P (*scenario experts*)
Target group	Internal project document, starting point of storyline development	External experts in Lima, mainly those partici-pating during RT II - IV
CIB scenario base and benchmark of com-parison	Scenario sample based on matrix no. 9	Scenario sample based on matrix no. 9 (and no. 10)
Sampling of scenarios (number and logic)	Translate the original CIB table of scenario selection: In total, all **16 CIB configurations** are covered through variants within the text e. g. in form of formulations like: "*Experts consid-ered that it would have been possible, too, that…*" Four **families** with internal **variants**: A: M1 and M2 (climate variants) B: B1 and B2 (actor variants and climate vari-ance) C D: M1 and D M2 (climate variants)	Translate first reduction of CIB table: In total **8 CIB reference configurations** are covered (climate variance in A and D and B2) Four **families** with internal **variants**: A: M1 and M2 (climate variants) B: B1 and B2 (actor variants and climate vari-ance) C D: M1 and D M2 (climate variants)
Length	Ca. 3 -4 pages per scenario family	1 page per scenario family

Annex U Illustration of the matching process at the examples 'tariffs' and 'poverty'

3a Specification

Example tariffs: "PEN/ m3 – an unanimous indicator with a narrow definition of the issue"

The definition of the numerical indicator for the descriptor tariffs, PEN/ m3, i.e. the price of drinking water per cubic meter was quasi already given in the verbal description of the descriptor. This means, the choice of this indicator was unanimous and unquestioned between all actors. Still, the existence of a shared numerical indicator did not mean that there was automatically a shared understanding, what the numerically defined water prices should cover and what not (cf. L t2 37).
Several consultations between modelers, issue expert and scenario experts and the use of the more extensive definitions of the descriptor in the descriptor essays were necessary to establish a shared understanding, what the numerical indicator PEN/m3 should cover and what not: Namely investment and operation costs only but not environmental costs, as these were difficult to quantify. Thus, the indicator was finally only a *partial* translation of the verbal ideas on tariffs that, in contrast, did include the coverage of environmental costs in the variant of 'cost effective tariffs' (see FN incl. WS tariffs I January 2012: 145, and FN WS tariffs II 20120606: 56). Furthermore, initially, the descriptor tariffs - as understood by the scenario group - had covered the prices consumers pay for water provided by the network as well as prices non connected users pay for water that is supplied by water tanks. In sum, multiple dimensions had been considered within this one descriptor. During the workshops with the issue experts, the definition of tariffs was refined by the modelers and scenarioexperts and limited to prices of water supplied by the water company *and* by the water network only.

Example poverty: "Socio-economic levels NSE - a contested indicator not matching the scenario groups' ideas behind the descriptor"

The definition of the indicator social levels NSE for the descriptor poverty was a contested one. There were conflicting interests between the perspectives of the different actors, namely the scenario group and the modelers (See FN January 2012). Especially the NGO members of the scenario group aimed at representing the issue of social inequality within the scenarios. Therefore, they proposed to work with *their* usual indicators for *monetary* poverty, namely with a) poverty by income (pobreza por ingresos) in reference to a basket of goods (Canasta Básica de Consumo, CBC), and to b) non-satisfaction of basic needs (necesidades básicas insatisfechas, NBI's). In contrast, the modelers, due to model requirements were not interested in a poverty indicator itself, but only into information on *water consumption* of different socio-economic groups. Thus, they proposed to work with the socio-economic levels NSE (niveles socio-economicos). This is the indicator also used by the water company SEDAPAL, who also provided information on the water consumption for the different socio-economic levels. Finally, *model requirements* drove the choice of this indicator and the modelers dominated this indicator selection (cf. L t3 35). This *model requirement* lead to the choice of an indicator not fully representing the ideas behind the descriptor and that is not used by the NGO stakeholders. Furthermore, the scenario group criticized the implicit SEDAPAL assumption that people from different socio-economic levels would 'need' different amounts of drinking water. In addition, the usage of the indicator NSE resulted in several imprecision which were made explicit in the descriptor essay (see DOC Descriptor essays final; interview L t3 35 and FN Nov_Dec 2012). In consequence, the use of the short label *poverty* for the indicator NSE was perceived as misleading. "*We may not, when we actually talk about the time-time-seriesseries, use the title of the descriptors, especially not in this case. It is misleading. LiWatool does not process 'poverty' but the 'distribution of the population onto the social levels A-E'. It is important to be more precise in wording!" (*FN March 2012: 492 et sq.; my comment).

3b Quantification

Example tariffs: "supposedly simple– and yet complex"

The definition of the *status quo* corresponded to the average price of water provided by SEDAPAL through the water network to different user groups (in PEN/ m3) in the (base year) 2011.[436] This average value was communicated to the issue experts of the LiWa project by the SUNASS, the authority approving the level of tariffs.[437] Thus, the definition of the status quo was in line with the official numbers used by the local stakeholders and was - to my knowledge - not contested. Due to the general change of the base year from 2009 to 2011, the status quo value (2009: 2,16 PEN/ m3) was adapted to 2,20 PEN/m3 in 2011.

To define *time-series* for this indicator**,** modelers, issue-experts on tariffs and scenario experts have translated scenario group statements on the two variants of 'cost-effective' and 'non-cost-effective tariffs' by some kind of 'verbal argumentative reasoning' (cf. FN January 2012 and FN WS tariffs II 20120606). The issue-experts proposed time-series that were based on official data on past development and on official future plans for infrastructure projects: This logic was chosen as any increase of water tariffs (decided by SUNASS) needs to be justified by concrete infrastructure projects of SEDAPAL. Both variants of tariff development were translated by an *increase* (inflation adjusted) based on the argumentation of the issue experts that a low increase is still not cost-effective and that a decrease is improbable. After the two workshops and bilateral consultation between modelers and issue experts in 2012, *lower* increase rates were assumed for both time-series, namely the (inflation adjusted) growth rates of 1% (instead of 3%) for 'C1 not cost-effective tariffs' and 3% (instead of 6%) for 'C2 cost-effective tariffs'. Furthermore, the time-series were adapted to the new (lower) status quo in 2011 and thus in consequence, the absolute price in 2040 became a bit lower, too, in the final version of input parameters. Finally, in 2040, the spread between both variants is of ca 3 vs. 5 PEN/m3 (inflation adjusted). To decide about the adequate numerical definition of the TS, the issue expert was pondering the *interrelations* between tariffs and other elements of the water system, as e. g. the issue of infrastructure – to assure consistency of this reasoning with the scenario groups assumptions, the CIB matrix was consulted by the scenario experts.

Example poverty: "no official future data available "

The *status quo* of the percentage of people belonging to the socio-economic levels (NSE) was - after a long discussion process between scenario experts, modelers and members of the scenario group from SEDAPAL and the NGOs - finally taken over from official data provided by APEIM,[438] an institution of the private economic sector, who provided latest data on the distribution of households in 2013. This latest information led to a considerable adaptation of the status quo assumed by the input data, defining ca. 40% of the population as belonging to the socio-economic levels D&E in the base year; instead of more than 50% and even 54%, which had been assumed before.

As to the *time-series*, initially, for each variant, two time-series were constructed, one for the development of the socio-economic levels D&E and one describing the development of the levels A-C grouped together.[439] No official prognosis or data on future development neither on the NSE nor on other poverty indicators was available, as the issue is *too politically sensible*. Scenario expert L (t3 35): *„In addition, we had the difficulty that nobody dared to make any prognosis or scenario, how the socio-economic levels might develop until the year 2040."* Thus the approach to define time-series used for other indicators, namely choosing from the array of existing projections and scenarios, was not working with regard to this issue. Even if some issue expertise on poverty was provided by the NGO partners of the local scenario group, there had not been any genuine re-

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436 Prices for water distributed through tanks were, in line with the definition of the indicator, not taken into account within this average value.

437 SUNASS: Superintendencia Nacional de Servicios de Saneamiento. See the justification of the status quo value in the descriptor essay on tariffs (see Annex Y).

438 APEIM: Asociación Peruana de Empresas de Investigación de Mercados, a non-profit organization that is representing the Peruvian enterprises doing market research and research on public opinion.

439 With regard to poverty, see FN January 2012: 186-198.

search done within the LiWa project on the future developments of the issue (see also interview L t3 74). The scenario group had made qualitative and also quantitative ad hoc estimation on possible future developments during the definition of the CIB variants in the descriptor essays (like “increases until 2040 by 15 %”). These estimations had referred to possible future developments of *monetary* poverty (see section on specification above), and not to the indicator NSE. Still, as no other estimations on future developments and especially not on alternative ones had been available, the estimations of the scenario group regarding *monetary* poverty were taken over by the modelers and scenario experts to define the first time-series on the development of the indicator *NSE* (split into the two TS D&E, A-C).

Translation of D&V into indicators and time-series, examples tariffs and poverty

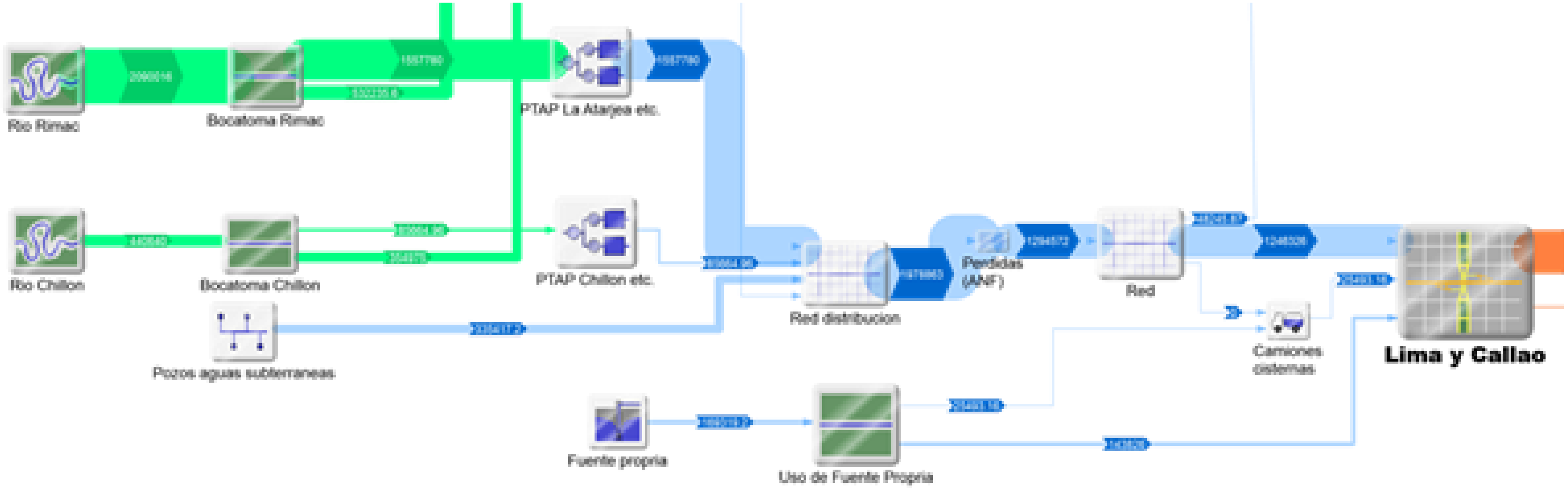
See DOC final descriptor essays and DOC scenarioquantification 20130502.

<table>
<tr><th colspan="2">Qualitative definition
(see descriptor essay)</th><th colspan="2">Quantitative definition
(see input parameter sheet)</th></tr>
<tr><th>descriptor</th><th>variants</th><th>indicator
(base year: status quo)</th><th>time-series</th></tr>
<tr><td rowspan="2">C ‘Tariffs’
“Tarifa de agua se define como el precio que los usuarios pagan por el servicio de agua potable y alcantarillado. En este estudio, tarifa de agua se refiere tanto al servicio que brinda Sedapal a través de la red pública, como al servicio de los camiones cisterna. La definición reúne tres criterios, el tipo de servicio (convencional o no convencional), la inclusión de servicios adicionales (tratamiento de aguas residuales y/o servicios ambientales) y la inclusión de subsidios o no . Dentro de la definición de tarifa de agua se incluye también lo que cobran los camiones cisterna a las personas que no tienen red pública de abastecimiento”</td><td>C 1 Tarifa de agua no sincerada (no cubriendo los costos reales – relativamente bajo)</td><td rowspan="2">PEN/ m3
(2009: 2,16)</td><td>exponential increase of 1% per year until 2040</td></tr>
<tr><td>C 2 Tarifa de agua no sincerada (cubriendo los costos reales – relativamente alto)</td><td>exponential increase of 3% per year until 2040</td></tr>
<tr><td rowspan="3">E ‘Urban poverty’
“ .se define a partir de dos aspectos centrales: Pobreza por ingresos y por necesidades básicas insatisfechas (NBI’s):
La pobreza por ingresos se determina a partir de una línea de pobreza pre-establecida que puede ser de acuerdo a una Canasta Básica de Consumo (CBC), la cual incluye gastos por alimentación y otros bienes básicos para medir la pobreza extrema de acuerdo al ingreso se utiliza la Canasta Básica de Alimentos (CBA), que es el gasto para cubrir un mínimo de requerimientos nutricionales.
La pobreza también puede medirse a través de las Necesidades Básicas Insatisfechas (NBI). El INEI ha determinado cinco de estas: (1) Vivienda con características físicas inadecuadas, (2) viviendas con hacinamiento, (3) viviendas sin desagüe, (4) hogares con niños que no asisten a la escuela y (5) hogares con alta dependencia económica.”</td><td>E 1: La pobreza en Lima y el Callao aumemta en 5% por quinquenio. (pobreza monetaria)</td><td rowspan="3">% of persons belonging to the socio-economic levels D+ E
(2013: 40,3 %)</td><td>linear in-crease up to 45% in 2040 (ca. +1,116 % per year)</td></tr>
<tr><td>E 2: Pobreza en Lima y el Callao se mantiene (pobreza monetaria)</td><td>Constant at 40,3%</td></tr>
<tr><td>E 3: La pobreza de Lima y el callao desciende en 50% (pobreza monetaria)</td><td>Linear de-crease to 30% in 2040 (ca. -0,745 % per year)</td></tr>
</table>

Annex V Vizualization of LiWatool (example for a Sankey diagram)

The empirical model in one block (water supply side represented only)

Source: Schütze 2015: 25



Annex W Defining criteria and the relation of scenarios and policies (Lima Water)

Defining model output or criteria

Initially, the cooperation between scenario experts and modelers to develop *criteria,* i.e. model *output* variables did not work easily and this task was left to the modelers alone. The need to define criteria was expressed at early stages of the project, but no concise definition of criteria (sets) which might be used by stakeholders and decision makers, when comparing options for action, was achieved until rather late in the process. In the end, the modelers provided criteria by ad-hoc definitions, without going thorough consultation process. For more information on the final criteria chosen see Schütze/ Alex 2014.

Scenario experts did not know enough about LiWatool to propose model outputs and also had a different understanding of what *criteria* could be. The modelers felt left alone with this task and were rather uncertain about developing useful ones. Finally, some cooperation on the definition between modelers and scenario experts has been achieved with regard to the definition of water consumption and of the water balance. Scenario experts were trying to understand LiWatool calculation logic and modelers were explaining LiWatool's reasoning in qualitative terms but no comprehensive and deep understanding was achieved, possibly due to missing resources (mainly time and method expertise), as both modelers and scenario experts suggested.

The relation of scenarios and policies in the LiWa scenarios

First, there were diverging understandings between modelers and scenario experts on how strictly one needs to distinguish between scenarios and policies. Initially, the construction of LiWatool had not been focusing the simulation of scenarios according to the CIB, but on testing different policy options within *one* context scenario. Thus, for the modelers and their simulation purpose, namely to compare different policies under the same scenario, policies need to be separated from scenarios. Instead, for scenario experts, general ideas on policies are integral part of different scenarios as these are causing future change.

Second, it was an issue, how strictly the modelers are determined by the scenarios in their policy simulations. During public simulation of measures, ad hoc measures were simulated that were not consistent with the chosen scenario. Still, the reasons for this remained unclear: Have the scenario ideas not been present or not been well understood? Did actors not accept the restrictions or guidance through the scenarios?

Overall, during the discussions, how strictly scenarios need to be separated from policies, which came up at several occasions, there was a slight undertone by the modelers. It suggested that these felt at the same time disempowered by scenarios as they were limited in their simulation decisions (straightjacket CIB), *and* not guided clearly enough by the qualitative scenario formulations, which were perceived as too vague.

Annex X Two central versions of the integrated scenarios (Lima Water)

Legend: Changes marked in *italic type.*

Type	**Scenario brochure V1 (21.03.2012) "INTEGRATION"**	**Scenario brochure V2 (Mai 2013) "ITERATION"**
DOC	Scenario brochure 20130321	Scenario brochure final 201305
Date of production	January – March 2012	April 2012
Language	Spanish	Spanish
Main authors	Scenario experts and modelers	Scenario experts, modelers and scenario group
Target group	External experts in Lima, mainly those contributing to the definition of an action plan.)	External experts in Lima (those using products of the LiWa project)
CIB scenario base and benchmark of comparison	Scenario sample based on LiWa9.cim/ LiWa10cim	a) Scenario sample based on LiWa9.cim/ LiWa10cim *b) Last minute change of scenario C into a less extreme one (independent of CIB matrix and sample)*
Sampling of scenari-os (number and logic)	Translate second simplification of CIB tableau: In total, **7 CIB reference configurations** are covered (climate variance in A and D, B and C only under dry climate change) Four **families** with internal **variants**: A: M1 and M2 (climate variants) B: B1 and B2 (actor Variants) C D: M1 and D M2 (climate variants) *(see Annex EE)*	Translate second simplification of CIB tableau: In total, **6 CIB reference configurations** are covered (climate variance in A and D, B and C only under dry climate change) Four **families** with internal **variants**: A: M1 and M2 (climate variants) B: B1 and B2 (actor Variants) C: *changed into a less negative one, inde-pendently of CIB information* D: M1 and D M2 (climate variants) *(see Annex FF)*
Basis of narrative parts	Short versions of Storylines after RT II Authors: scenario experts	Short versions of Storylines after RT II Authors: scenario experts
Basis of numerical parts	LiWatool simulation using TS V1 Authors: modelers but based on definitions from the scenario group	Simulation using TS V2 Authors: modelers, but based on definitions from the scenario group
Length	Ca. 8 pages per scenario (including narrative, simulation input and results, graphics and illustrations and free space) ; mere storyline text ca.2 pages per scenario family, annex containing tables with simulation input and output across scenarios.	Ca. 8 pages per scenario (including narrative, simulation input and results, graphics and illustrations and free space) ; mere storyline text ca.2 pages per scenario family, annex containing tables with simulation input and output across scenarios.

Annex Y Example for a descriptor essay (issue: tariffs)

(Source: DOC descriptor essays final)

Descriptor

C. Tarifas de agua

1. Definición del descriptor

- Tarifa de agua se define como el precio que los usuarios pagan por el servicio de agua potable y alcantarillado. En este estudio, tarifa de agua se refiere al servicio que brinda Sedapal a través de la red pública. No se analiza la tarifa que se cobra por el suministro de agua por camiones cisterna.[440]

2. Relevancia/importancia para el tema

- La tarifa es importante por dos razones: Primero, sirve para cubrir los costos del servicio por parte de SEDAPAL, incluyendo tanto los costos de inversión como los costos de operación y mantenimiento. Segundo, puede llegar a ser una medida de control de la demanda (si la tarifa es alta la tendencia del consumo será baja, si la tarifa es baja ocurriría lo contrario) y promover el uso sostenible del recurso de agua (Olmstead & Stavins 2009).

3. Principales factores de influencia (driving forces)

- Factores político: La <u>forma de gobierno</u> es una influencia constante en la determinación de la tarifa. La tarifa no es determinada directamente por SEDAPAL, sino por la Superintendencia Nacional de Servicios de Saneamiento (SUNASS) que a su vez depende de la Presidencia del Consejo de Ministros (PCM). Es bien probable que, hasta el momento, esa interferencia política haya limitado subidas de la tarifa para el servicio porque se considera que esta medida sería impopular y generaría reclamos por parte de la población. La <u>gestión de las cuencas</u> también tendrá un impacto en la determinación de las tarifas. La Autoridad de Agua (ANA) impone a SEDAPAL una retribución económica por el uso de agua que se toma en cuenta para la determinación de la tarifa de agua como costo operativo. Se supone que mejoramientos de la gestión de la cuenca resulten en incrementos de esa retribución.
- <u>Factores de gestión: La empresa</u> plantea la tarifa a partir de un presupuesto necesario para continuar y ampliar sus operaciones; sin embargo, por sí sola no la determina, requiere de los parámetros que la SUNASS establezca en esta materia. Siendo la SUNASS un ente administrativamente autónomo pero dependiente del Poder Ejecutivo, la determinación de la tarifa escapa, hasta cierto punto, de las decisiones técnicas de la empresa. En el escenario de una inclusión de sistemas de <u>tratamiento de aguas residuales</u> se podría dar una influencia al sistema de tarifas ya que eso elevaría por mucho los costos de producción. Por otro lado la población puede presionar a la empresa de mantener tarifas no sinceradas en caso que su performance no sea eficiente en sentido de contar con pérdidas altas.

[440] Aproximadamente un millon de Limeños se abastecen por camiones cisternas (SUNASS 2010a). Según un estudio realizado en 2004 pagan entre PEN 5.65 y 7.41 por m^3, es decir hasta cinco veces más que usuarios servidos por red pública (Chirinos Gómez et al. 2004).

- Factores sociales: La pobreza urbana es un factor importante para la fijación de tarifas, dado que la carencia de recursos de la población puede requerir que se mantenga una tarifa baja que limita los recursos de la empresa (si el estado no compensa esta falta de la capacidad de pago con subsidios directos). El crecimiento de la población y la expansión de la ciudad aumentan la presión por los servicios básicos, por lo que un alza en las tarifas sería necesaria para cubrir los gastos en infraestructura y otros aspectos del servicio que sean demandados.

4. Estado actual y tendencias en el pasado (Datos y estadísticas)

- La tarifa media de los servicios convencionales (red pública de Sedapal) por m^3 ha subido de manera lenta pero constante durante los últimos años:

Año	2005	2006	2007	2008	2009	2010	2011	2012
Tarifa media (PEN/m3)	1,41	1,61	1,79	1,92	2,16	2,24	2,57	2,65

Fuentes: SUNASS 2010b, 2011, comunicación personal con Daniel Gala

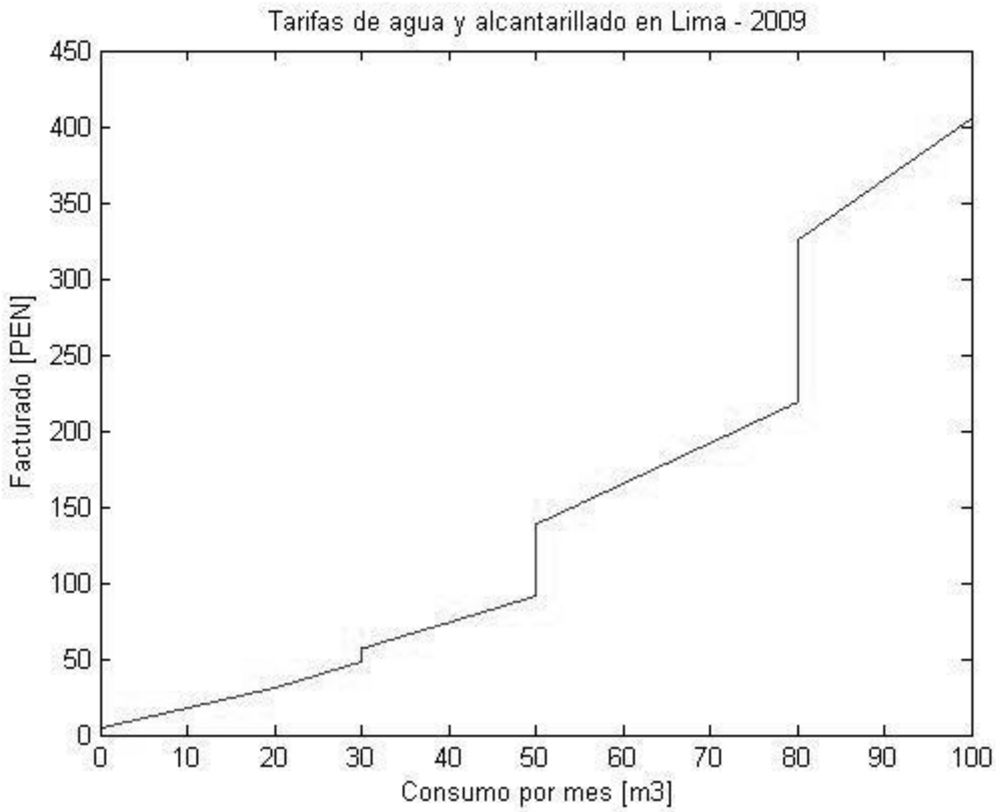
(SUNASS, 6 de Julio de 2012)

- La tarifa media se traduce en una estructura tarifaria que incluye un cargo fijo y un cargo por volumen de consumo y que se diferencia por clases y categorias de usuarios y rangos de consumo. La siguiente tabla muestra la estructura tarifaria vigente en el año base 2009:

Cargo Fijo (PEN/mes)			4,444
Cargo por volumen			
Clase	Categoría	Rangos (m^3/mes)	Tarifa (PEN/m^3)
Residencial	Social	0 a más	1,311
	Doméstico	0 a 20	1,311
		20 a 30	1,735
		30 a 50	2,675
		50 a 80	2,675
		80 a más	4,005
No residencial	Comercial	0 a más	5,291
	Industrial	0 a más	5,291
	Estatal	0 a más	2,675

Fuente: El Peruano (2008)

Con eso se llega a un sistema tarifario escalonado para los usuarios domésticos como demostrado en el siguiente gráfico:



Fuente: ifak, baseado en El Peruano (2008)

- La SUNASS determina la tarifa a base de un modelo que incluye costos de inversión y de operación y mantenemiento, relacionado tanto con el suministro de agua potable como la recolección y el tratamiento de aguas residuales. También considera las retribuciones economicas pagadas por SEDAPAL a la ANA, que actualmente tienen un valor marginal de no más de PEN 0.02 por m^3 (El Peruano 2011). No obstante el modelo se refiere a funcciones de costos de una “empresa eficiente”, no a los costos reales de Sedapal.

5. Pronósticos, Planes en el futuro

- Para el quinquenio 2010-2015 se permiten los siguientes incrementos de la tarifa media para el (más posibles ajustes por la tasa de crecimiento del Indice de Precios al por Mayor):

Año	Incremento tarifario
1	2,0 %
2	2,0 %
3	2,3 %
4	0,0 %
5	0,0 %

Adicionalmente se preveen los siguientes incrementos tarifarios condicionados por proyecto:

Proyecto de infraestructura	Incremento	Metas de Gestión asociadas al incremento tarifario propuesto
PTAR La Chira	6.0 %	6.5 m^3/s
Proyecto de Abastecimiento de Agua, Recolección y Tratamiento de Aguas Residuales “Mancomunidad del Sur” de Lima	2.1 %	Hasta 250 lps
Portafolio Condicionado de Proyectos de Ampliación de Cobertura de Agua y Alcantarillado y de Rehabilitación de las Redes	5.2%	67.667 conexiones de agua 73.197 conexiones de alcantarillado 302.177 micromedidores
Transvase Marca II	3,9 %	4,6 m^3/s
Ramal Sur y obras complementarias al proyecto Transvase Marca II	3,1 %	

Fuente: El Peruano (2010)

- En el año 2010 se ha implementado una diferenciación de la estructura tarifaria por servicios de agua potable y servicios de alcantarillado (El Peruano 2010). Esa diferenciación has sido de carácter informativo y no ha afectado la tarifa media ni el monto total que los usuarios pagan por m^3.
- Para los próximos años se planea también una diferenciación de la estructura tarifaria para usuarios domésticos por niveles socioeconomicos (NSE). La estructura tarifaria pues debe discriminar entre usuarios no pobres (NSE A-C), pobres (NSE D) y extremamente pobres (NSE E). Ese cambio estrucutural tampoco va a afectar al nivel de la tarifa media.
- Luego la tarifa podría convertirse en una fuente de recursos para el mantenimiento de la cuenca, en caso se incluya el pago por servicios ambientales (aunque todavía se excluye legalmente la inclusión de costos no empresariales en la calculación de la tarifa).

6. Posibles desarrollos y cuantificación

- Se consideran dos posible desarrollos extremos:
  1. Tarifa de agua no sincerada (no cubriendo los costos reales – relativamente bajo)
  2. Tarifa de agua sincerada (cubriendo los costos reales – relativamente alto)

  Se entiende como “tarifa sincerada” un sistema tarifario que considera todos los costos reales (Rogers et al. 2002):

  - Los costos empresariales de inversión y operación y mantenemiento relacionado con la producción de agua potable y la recolección y el tratamiento de aguas residuales
  - Los costos externos (o sociales) relacionado con la escasez del recurso y con los effectos ambientales de la extracción de agua y la descarga de aguas residuales no tratadas.

  En cambio una tarifa “no sincerada” se refiere a un sistema tarifario que no cubre todos los costos a lo largo de la captación, producción y el suministro. Se supone que una tarifa sincerada siempre será más alta que la no sincerada. Segun la información tanto de SEDAPAL como de la SUNASS los dos posibles desarrollos coinciderán con incrementos tarifarios – ya que el costo del suministro de agua subirá en todo caso por aumentos en la escasez de agua y la necesidad de realizar inversiones adicionales en la infraestructura para poder explorar nuevas fuentes de agua.

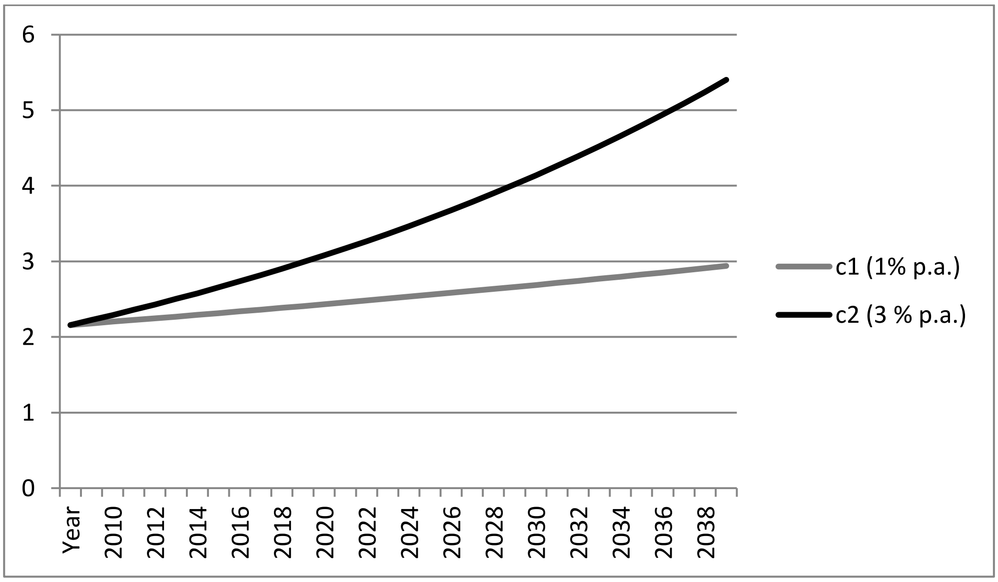
Se asume que una tarifa sincerada puede alcanzar estas subidas de costo mientras que la tarifa no sincerada siempre queda atrás de ellos. Esto quiere decir que con una tarifa no sincerada tanto la recuperación de costos como los incentivos para ahorrar el agua siempre quedan imperfectos.

La siguiente table muestra la cuantificación de los dos desarrollos posibles para las simulaciones en LiWatool:

Indicador	Desarrollo	2040	Suposiciones	Fuente
Tarifa para el servicio de agua y alcantarillado en la red de Sedapal [PEN/m3]	Aumento linear de 1% hasta 2040	2,94 PEN/m3	Inversiones moderadas hasta 2030	Communi-caciones personales con Iván Lucich (SUNASS, 30 de marzo de 2011) y William Acosta (SEDAPAL, 31 de marzo de 2011)
	Aumento linear de 3% hasta 2040	5,40 PEN/m3	Inversiones fuertes y altos costo de suministro de agua	

Para la cuantificación se ha multiplicado la tarifa media del año 2009 (PEN 2,16/m^3) con el aumento anual corespondiente (1% o 3% p.a.).

- El siguiente gráfico muestra la evolución de la tarifa no sincerada (c1) y sincerada (c2) hasta el añ0 2040 (fuente: ifak):



Estas cuantificaciones se basan a las siguientes suposiciones:

   - Se refieren solamente a los costos empresariales de inversion y operación y mantenimiento por parte de SEDAPAL
   - No incluyen los costos externos del suministro de agua ya que son muy difíciles de estimar y faltan estudios apropriados. Eso quiere decir, por ejemplo, que se supone que la retribución económica impuesto por la ANA no se aumente de manera significante.
   - No incluyen los ajustes por inflación (tasa de crecimiento del Indice de Precios al por Mayor). En este sentido, las cuantificaciones se refieren a incrementos tarifarios reales. Se assume que la tasa de inflación coincide con una parecida tasa de crecimiento del costo de los factores de producción (tanto de materiales como sueldos). Por eso incrementos tarifarios asociados con la inflación no generan fondos adicionales para SEDAPAL ni implican un mejor control de la demanda.
   - No incluyen el Impuesto al Valor Agregado (IVA).

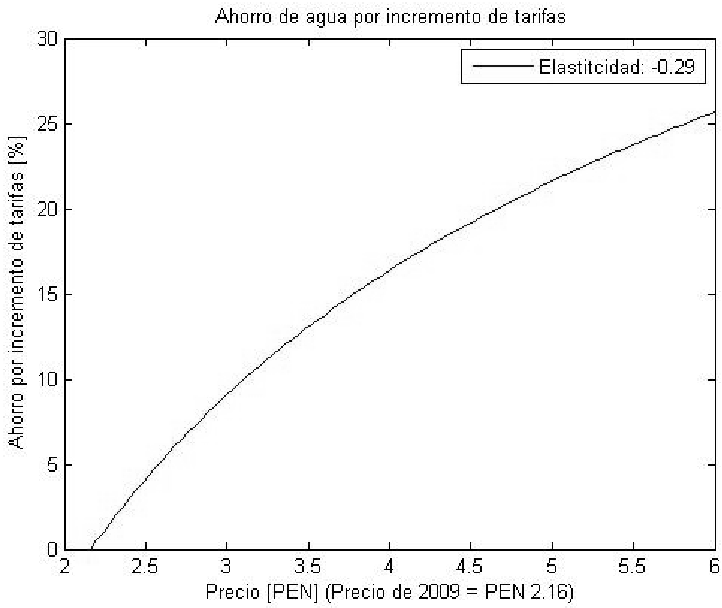
  Tomando en cuenta estas suposiciones, la cuantificación para una tarifa sincerada se entiende como un valor mínimo.

- Se supone que incrementos tarifarios induzcan reducciones del consumo de agua por persona. Esta relación refleja la elasticidad precio del consumo ε. Una elasticidad de ε=(-0.5) significa, por ejemplo, que un incremento tarifario por 1% resulte en una reducción del consumo por 0.5%. Matematicamente se ha incorporado esta relación para las simulaciones de los escenarios por LiWatool de la siguiente manera:

$$x_1 = x0 \quad * \left(\frac{p_1}{p_0}\right)^{\varepsilon}$$

  en que x_0 y p_0 corresponden a los niveles de la demanda y la tarifa antes del incremento tarifario, y x_1 y p_1 a los niveles después. Estimaciones empíricas de la demanda precio revelan un rango desde -0.1 hasta -0.6 (vease por ejemplo Worthington & Hoffman 2008). Para la simulación en LiWatool se usa un valor de -0.29 como lo uso la SUNASS para sus estudios tarifarios (SUNASS 2006, p. 41).

El siguiente gráfico demuestra los ahorros porcentuales del consumo de agua que resultan de incrementos tarifarios (comparado con el nivel del año 2009):



Fuente: ifak

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Annex Z Final CIB matrix “Lima’s Water futures 2040”, matrix no. 9 (Lima Water)

	A		B			C		D			E			F			G		H		I		J			K		L			M		
	A1	A2	B1	B2	B3	C1	C2	D1	D2	D3	E1	E2	E3	F1	F2	F3	G1	G2	H1	H2	I1	I2	J1	J2	J3	K1	K2	L1	L2	L3	M1	M2	M3
A. Government																																	
Government with decision power and vision			0	2	-2	-3	3	-1	0	1	-3	1	2	-2	0	2	0	0	3	-3	3	-3	-1	-1	2	-3	3	3	0	-3	-1	2	-1
Government without decision power and without vision			1	-3	2	3	-3	1	0	-1	2	1	-3	1	1	-2	0	0	-3	3	-3	3	1	1	-2	2	-2	-3	0	3	1	-2	1
B. Water company																																	
Private owned company	0	0				-3	3	0	0	0	1	0	-1	0	0	0	-2	2	0	0	0	0	-1	-1	2	-1	1	-3	0	3	-1	2	-1
Public company with autonomy from the government	0	0				-3	3	0	0	0	-2	0	2	-1	-1	2	-2	2	0	0	1	-1	-2	-1	3	-1	1	3	0	-3	-1	2	-1
Public company depending from the government	0	0				0	0	0	0	0	0	0	0	0	0	0	2	-2	0	0	-1	1	2	0	-2	2	-2	1	0	-1	0	0	0
C. Water tariffs																																	
Low (non cost-covering) tariffs	0	0	-2	1	1			0	0	0	0	0	0	3	-1	-2	1	-1	0	0	0	0	2	-1	-1	0	0	-1	0	1	0	0	0
High (cost-covering) tariffs	0	0	0	0	0			0	0	0	0	0	0	-3	1	2	-1	1	0	0	0	0	-2	1	1	-1	1	2	0	-2	0	0	0
D. Population																																	
High population growth	0	0	0	0	0	0	0				0	0	0	0	0	0	2	-2	0	0	-2	2	2	1	-3	0	0	3	0	-3	2	-2	0
Moderate population growth	0	0	0	0	0	0	0				0	0	0	0	0	0	1	-1	0	0	1	-1	1	0	-1	0	0	2	0	-2	1	-1	0
Low population growth	0	0	0	0	0	0	0				0	0	0	0	0	0	0	0	0	0	2	-2	-1	0	1	0	0	1	0	-1	-1	1	0
E. Urban poverty																																	
Increasing poverty	-3	3	0	0	0	0	0	2	1	-3				-3	1	2	2	-2	0	0	-3	3	0	0	0	0	0	0	0	0	2	-2	0
Constant poverty	-1	1	0	0	0	0	0	1	0	-1				0	0	0	0	0	0	0	-1	1	0	0	0	0	0	0	0	0	1	-1	0
Decreasing poverty	2	-2	0	0	0	0	0	-2	0	2				3	-1	-2	-2	2	0	0	2	-2	0	0	0	0	0	0	0	0	-1	1	0
F. Water consumption																																	
Increasing per capita water consumption	0	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	2	0	-2	0	0	0	0	0	0	0	0
Constant per capita water consumption	0	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Decreasing per capita water consumption	0	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	-2	0	2	0	0	0	0	0	0	0	0
G. Water network losses																																	
Increasing water network losses	0	0	0	0	0	-1	1	0	0	0	0	0	0	0	0	0			0	0	0	0	2	1	-3	0	0	2	0	-2	0	0	0
Decreasing water network losses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	-2	-1	3	0	0	-2	0	2	0	0	0
H. Catchment management																																	
Integrated and participatory catchment management	1	-1	0	0	0	-1	1	0	0	0	-1	0	1	-1	0	1	0	0			2	-2	-3	1	2	-2	2	2	0	-2	-1	2	-1
Catchment management without integration	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-1	0	0			-2	2	2	-1	-1	2	-2	-2	0	2	1	-2	1
I. Urban development																																	
City with urban planning and green areas	1	-1	0	0	0	0	0	-2	-1	3	-1	0	1	0	0	0	0	0	0	0			-1	0	1	-2	2	1	0	-1	-1	2	-1
City without urban planning and with few green areas	-1	1	0	0	0	0	0	2	1	-3	1	0	-1	0	0	0	1	-1	0	0			1	0	-1	0	0	0	0	0	1	-3	2
J. Water coverage																																	
Decreasing coverage rate	0	0	1	-1	0	0	0	0	0	0	2	0	-2	-2	0	2	0	0	0	0	-1	1				0	0	0	0	0	0	0	0
Constant coverage rate	0	0	0	0	0	0	0	0	0	0	1	0	-1	-1	0	1	0	0	0	0	0	0				0	0	0	0	0	0	0	0
Increasing coverage rate	0	0	-1	1	0	0	0	0	0	0	-2	0	2	2	0	-2	0	0	0	0	1	-1				0	0	0	0	0	0	0	0
K. Wastewater treatment/reuse																																	
Increasing wastewater treatment and reuse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-3	3	1	0	-1			1	0	-1	0	0	0
Constant wastewater treatment and reuse	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	2	0	0	0	0	3	-3	-2	0	2			-1	1	0	0	0	0
L. Water sources																																	
Increasing water sources	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-1	0	0	0	0	2	-2	-2	0	2	2	-2				0	0	0
Constant water sources	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	1	-1	0	1	0	0				0	0	0
Decreasing water sources	0	0	0	0	0	0	0	0	0	0	0	0	0	-3	0	3	0	0	0	0	-2	2	3	0	-3	-2	2				0	0	0
M. Water flow in rivers																																	
Excessive water flow (flooding)	1	-1	0	0	0	0	0	0	0	0	3	0	-3	-1	0	1	1	-1	2	-2	-1	1	2	0	-2	1	-1	-3	1	2			
Increasing water flow without risks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	-2	0	2	0	0	2	-1	-1			
Low water flow (severe droughts)	1	-1	0	0	0	0	0	1	0	-1	2	0	-2	-2	-1	3	0	0	3	-3	-2	2	3	-1	-2	-2	2	-2	-1	3			

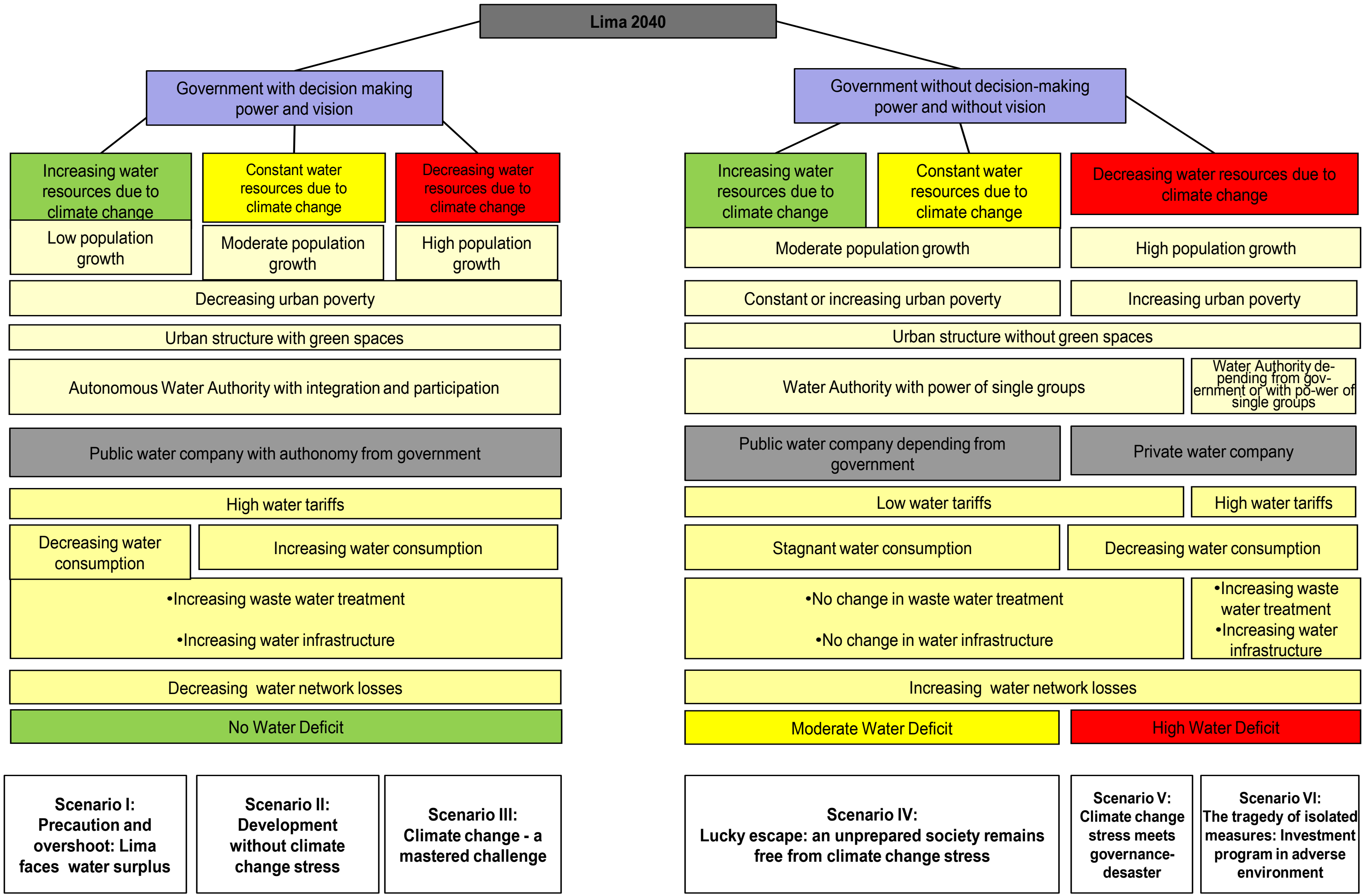
Annex AA Ensemble analysis: Dissent between matrix no. 4 and no. 6 (Lima Water)

(Note that for the ensemble analysis the number of D&V had to be equalized.)

	A		B			C		D			E			F			G		H			I			J			K		L			M		
	A1	A2	B1	B2	B3	C1	C2	D1	D2	D3	E1	E2	E3	F1	F2	F3	G1	G2	H1	H2	H3	I1	I2		J1	J2	J3	K1	K2	L1	L2	L3	M1	M2	M3
A Regierungsform																																			
A1 Regierung mit Entscheidungskraft und Vision			1	1	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0	3	2	1	0	0	0	0	0	0	0	0	0	0	0
A2 Regierung ohne Entscheidungskraft und Vision			0	0	0	0	0	1	0	1	1	1	1	1	1	1	0	0	0	1	1	3	1	2	0	0	0	0	0	0	0	0	0	0	0
B Wasserunternehmen																																			
B1 Privatisierung	0	0				1	1	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2 Staatlich mit Autonomie	0	0				1	1	0	0	0	0	1	1	1	0	1	1	1	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0
B3 Staatlich ohne Autonomie	0	0				0	0	0	0	0	2	1	2	1	1	1	2	2	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
C Wassertarife																																			
C1 Niedrige Tarife	0	0	0	0	0			0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
C2 Hohe Tarife	0	0	0	0	0			0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
D Demografie																																			
D1 Hohes Bevölkerungswachstum	1	1	0	0	0	0	0				2	0	2	2	1	1	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
D2 Mittleres Bevölkerungswachstum	1	1	0	0	0	0	0				1	0	1	1	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
D3 Niedriges Bevölkerungswachstum	1	1	0	0	0	0	0				1	1	2	1	1	2	2	2	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
E Armut																																			
E1 Wachsende Armut	1	1	0	0	0	1	1	0	0	0				1	1	1	0	0	0	0	0	2	1	2	0	0	0	0	0	0	0	0	0	0	0
E2 Gleichbleibende Armut	1	1	0	0	0	1	1	0	1	1				1	0	1	1	1	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0
E3 Sinkende Armut	1	1	0	0	0	1	1	0	1	1				0	0	0	0	0	0	0	0	2	1	2	0	0	0	0	0	0	0	0	0	0	0
F Wasserkonsum in Haushalten																																			
F1 Erhöhter Wasserkonsum	0	0	0	0	0	1	1	0	0	0	1	0	1				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F2 Stagnierender Wasserkonsum	0	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F3 Sinkender Wasserkonsum	0	0	0	0	0	1	1	0	0	0	1	0	1				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G Wasserverluste im Netz																																			
G1 Steigende Wasserverluste	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G2 Sinkende Wasserverluste	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H Einzugsgebietsmanagement																																			
H1 Autonome Wasserbehörde mit Integration und Partizipation	1	1	0	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0				2	1	1	0	0	0	0	0	0	0	0	0	0	0
H2 Autonome Wasserbehörde mit Einfluss von Einzelgruppen	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0				1	0	1	0	0	0	0	0	0	0	0	0	0	0
H3 Wasserbehörde mit Abhängigkeit von Regierung	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	0	0				1	1	1	0	0	0	0	0	0	0	0	0	0	0
I Stadtentwicklung																																			
I1 Stadtstruktur ohne Grünflächen	0	0	0	0	0	1	1	1	0	1	1	0	1	2	0	2	1	1	0	0	0				1	0	1	2	2	1	0	1	0	0	0
I2 Stadtstruktur mit Grünflächen	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0				1	0	1	1	1	1	0	1	0	0	0
I3 XXX	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	1	1	1	0	0	0				0	0	0	1	1	2	1	1	0	0	0
J Wasserdefizit																																			
J1 Hohes Wasserdefizit	0	0	1	1	2	0	0	1	1	1	2	1	3	3	0	3	1	1	1	1	1	1	1	0				1	1	3	1	3	0	0	0
J2 Mittleres Wasserdefizit	0	0	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	0	0				1	1	1	0	1	0	0	0
J3 Kein Wasserdefizit	0	0	1	0	1	0	0	1	1	2	2	1	3	3	0	3	1	1	1	0	1	1	1	0				1	1	1	0	1	0	0	0
K Abwasserbehandlung																																			
K1 Abwasserbehandlung auf Bewässerungsqualität wie heute	0	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	1	2	0	1	1			0	0	0	0	0	0
K2 Abwasserbehandlung auf Bewässerungsqualität steigt	0	0	0	0	0	1	1	0	0	0	1	0	1	1	1	1	1	1	0	0	0	2	1	1	1	1	0			0	0	0	0	0	0
L Wasserdargebot (Infrastruktur)																																			
L1 Stark steigendes Infrastrukturdargebot	0	0	0	0	0	2	2	1	1	2	0	0	0	1	0	1	2	2	0	0	0	2	1	1	0	0	0	0	0				0	0	0
L2 Unverändertes Infrastrukturdargebot (wie 2009)	0	0	0	0	0	1	1	1	1	1	0	0	0	1	1	1	1	1	0	0	0	1	0	1	0	0	0	0	0				0	0	0
L3 Sinkendes Infrastrukturdargebot	0	0	0	0	0	2	2	1	1	1	0	0	0	1	0	1	1	1	0	0	0	2	1	1	0	0	0	0	0				0	0	0
M Klimabedingte Veränderung des Wasserdargebots																																			
M1 Zunahme Dargebot	1	1	0	0	0	1	1	1	1	2	2	0	2	1	0	1	1	1	1	1	1	1	0	1	1	1	2	0	0	0	0	0			
M2 Unverändertes Dargebot (wie 2009)	1	1	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	0	0	0	0	0			
M3 Abnahme des Dargebots	1	1	0	0	0	1	1	1	1	1	0	0	0	1	1	2	0	0	2	1	1	0	1	1	0	0	0	0	0	0	0	0			

Annex BB First scenario sample based on CIB matrix no. 4, plus short scenario description (Lima Water)

Sample based on the CIB matrix no. 4, at the occasion of the milestone report summer 2010. (Source: DOC ZB_IWS_ZIRIUS 2010)



Short description of the scenarios

I: Precaution and overshoot: Lima faces water surplus

An alarmed and capable society takes determined measures. A surprisingly favourable climate change (regarding the local water resources) may lead in the end to more than water deficit compensation. Although this scenario might be unlikely and should be not misunderstood as an appeal to inactivity, it is part of the space of possibilities.

II: Development without climate change stress

A moderate climate development avoids stress factors (water resource decrease, rural exodus) and issues no severe challenges to capable water governance. The water deficit can be safely compensated and the growing water demand of a prospering metropolis can be satisfied by determined infrastructure measures.

III: Climate change - a mastered challenge

An alarmed and capable society takes determined measures (organisational, infrastructure, savings) to respond to the challenge of a severe climate change stress (water resource decrease, rural exodus) and narrowly succeeds (although a failure was not impossible).

IV: Lucky escape: an unprepared society remains free from climate change stress

An inactive society tries its luck. No determined measures are taken to improve the water supply and to prepare for climate change. A positive climate development justifies the policy of inaction to some extent, but it leaves Lima behind with its unsolved home-made water problems.

V: Climate stress meets governance-disaster

An inactive society with unprepared water governance faces the cruelty of a severe climate change. Decreasing water resources, rural exodus and a neglected infrastructure combine to a desperate situation. This scenario marks the worst case of the LiWa scenario set. No final judgement was made so far whether it should be considered also as the non-suprise/trend scenario.

VI: The tragedy of isolated measures: Investment program in an adverse environment

In this scenario the water governance actors divide up into an active and an inactive part. While determined infrastructure measures are taken, other fields remain untreated and fail to back the undertaken measures with a supporting background.

Annex CC Scenario sample based on matrix no. 9, n= 16 configurations (Lima Water)

	Escenario A **Condiciones climáticas difíciles se suman a una gobernanza muy deficiente**	**Escenario B1:** **La tragedia de las medidas aisladas:** **La autoridad de gestión de cuencas como luchador solitario**	**Escenario B2** **La tragedia de las medidas aisladas:** **La empresa de agua privada como luchador solitario**	**Escenario C** **Las oportunidades de los actores a nivel meso**		**Escenario D** **Resiliencia climática por medio de la gobernanza**
	Config. no. 10, Config. no. 3, Config. no. 2, Config. no. 6	Config. no. 13, Config. no. 9	Config. no. 4/7, Config. no. 4/7, Config. no. 4, Config. no. 11	Config. no. 15	Config. no. 16, Config. no. 14, Config. no. 12	Config. no. 8, Config. no. 1
A Forma de Gobierno	A2 Gobierno sin poder de decisión y sin visión	A2 Gobierno sin poder de decisión y sin visión	A2 Gobierno sin poder de decisión y sin visión	A2 Gobierno sin poder de decisión y sin visión		A1 Gobierno con poder de decisión y con visión
H Gestión de las cuencas hidrográficas	H2 Gestión de las cuencas sin integración	H1 Gestión de las cuencas con integración	H2 Gestión de las cuencas sin integración	H1 Gestión de las cuencas con integración		H1 Gestión de las cuencas con integración
B Gestión de la empresa de agua	B3 Empresa de agua dependiente del gobierno	B3 Empresa de agua dependiente del gobierno	B1 Empresa de agua privada	B1 Empresa de agua privada		B2 Empresa de agua con autonomía del gobierno
C Tarifas de agua y saneamiento	C1 Tarifas de agua no sincerada	C1 Tarifas de agua no sincerada	C2 Tarifas de agua sincerada	C2 Tarifas de agua sincerada		C2 Tarifas de agua sincerada
D Demografía	D1 Crecimiento de la población alto	D1 Crecimiento de la población alto	D1 Crecimiento de la población alto	D1 Crecimiento de la población alto		D3 LCrecimiento de la población bajo
I Forma de desarrollo urbano	I2 Ciudad sin planificación y pocas áreas verdes	I2 Ciudad sin planificación y pocas áreas verdes	I2 Ciudad sin planificación y pocas áreas verdes	I2 Ciudad sin planificación y pocas áreas verdes		I1 I2 Ciudad con planificación y áreas verdes
E Pobreza urbana	E1 Pobreza urbana aumenta	E1 Pobreza urbana aumenta	E1 Pobreza urbana aumenta	E1 Pobreza urbana aumenta		E3 Pobreza urbana disminuye
J Cobertura en la red de agua	J1 Cobertura de agua disminuye	J1 Cobertura de agua disminuye	J1 Cobertura de agua disminuye	J1 Cobertura de agua disminuye	J2 Cobertura de agua constante	J3 Cobertura de agua aumenta

<table>
<tr><th></th><th colspan="4">Escenario A
Condiciones climáticas difíciles se suman a una gobernanza muy deficiente</th><th colspan="2">Escenario B1:
La tragedia de las medidas aisladas:
La autoridad de gestión de cuencas como luchador solitario</th><th colspan="4">Escenario B2
La tragedia de las medidas aisladas:
La empresa de agua privada como luchador solitario</th><th colspan="4">Escenario C
Las oportunidades de los actores a nivel meso</th><th colspan="2">Escenario D
Resiliencia climática por medio de la gobernanza</th></tr>
<tr><th></th><th>Config. no. 10</th><th>Config. no. 3</th><th>Config. no. 2</th><th>Config. no. 6</th><th>Config. no. 13</th><th>Config. no. 9</th><th>Config. no. 4/7</th><th>Config. no. 4/7</th><th>Config. no. 4</th><th>Config. no. 11</th><th>Config. no. 15</th><th>Config. no. 16</th><th>Config. no. 14</th><th>Config. no. 12</th><th>Config. no. 8</th><th>Config. no. 1</th></tr>
<tr><td>F Consumo de agua per cápita</td><td colspan="3">F3 Consumo per cápita de agua disminuye</td><td>F2 Consumo per cápita de agua se mantiene</td><td colspan="2">F3 Consumo per cápita de agua disminuye</td><td>F2 Consumo per cápita de agua se mantiene</td><td colspan="3">F3 Consumo per cápita de agua disminuye</td><td colspan="4">F3 Consumo per cápita de agua disminuye</td><td colspan="2">F3 Consumo per cápita de agua disminuye</td></tr>
<tr><td>G Pérdidas en la red</td><td colspan="4">G1 Pérdidas de agua aumentan</td><td colspan="2">G1 Pérdidas de agua aumentan</td><td colspan="4">G1 Pérdidas de agua aumentan</td><td colspan="4">G1 Pérdidas de agua aumentan</td><td colspan="2">G2 Pérdidas de agua disminuyen</td></tr>
<tr><td>K Tratamiento y reuso de aguas residuales</td><td colspan="4">K1 Tratamiento y reuso de aa.rr. se mantiene</td><td>K2 Tratamiento y reuso de aa.rr. aumenta</td><td>K1 Tratamiento y reuso de aa.rr. se mantiene</td><td colspan="3">K1 Tratamiento y reuso de aa.rr. se mantiene</td><td>K2 Tratamiento y reuso de aa.rr. aumenta</td><td colspan="4">K2 Tratamiento y reuso de aa.rr. aumenta</td><td colspan="2">K2 Tratamiento y reuso de aa.rr. aumenta</td></tr>
<tr><td>L Fuentes de agua por infraestructura</td><td colspan="2">L3 Fuentes de agua disminuyen</td><td colspan="2">L2 Fuentes de agua constantes</td><td>L2 Fuentes de agua constantes</td><td>L1 Fuentes de agua aumentan</td><td colspan="2">L2 Fuentes de agua constantes</td><td colspan="2">L3 Fuentes de agua disminuyen</td><td colspan="2">L3 Fuentes de agua disminuyen</td><td>L2 Fuentes de agua constantes</td><td>L1 Fuentes de agua aumentan</td><td colspan="2">L1 Fuentes de agua aumentan</td></tr>
<tr><td>M Cambio climático (caudal y riesgos)</td><td>M3 Caudal bajo (sequías graves)</td><td colspan="3">M1 Caudal de los ríos excesivo (inundaciones)</td><td colspan="2">M3 Caudal de los ríos bajo (sequías graves)</td><td colspan="3">M1 Caudal de los ríos excesivo (inundaciones)</td><td>M3 Caudal de los ríos bajo (sequías graves)</td><td colspan="4">M3 Caudal de los ríos bajo (sequías graves)</td><td>M3 Caudal bajo (sequías graves)</td><td>M2 Caudal de los ríos aumenta sin riesgos</td></tr>
</table>

Annex DD First simplification of the scenario sample, n= 8 configurations (Lima Water)

Selection of reference variants for RT II, changes indicated in light grey (see FN March 2012)

	Escenario A: Condiciones climáticas difíciles se suman a una gobernanza muy deficiente		**Escenario B: La tragedia de las medidas aisladas**			**Escenario C: Las oportunidades de los actores a nivel meso**	**Escenario D: Resiliencia climática por medio de la gobernanza**	
			Escenario B1: La autoridad de gestión de cuencas como luchador solitario	**Escenario B2: La empresa de agua privada como luchador solitario**				
	Config. no. 10	Config. no. 3	Config. no. 9	Config. no. 4	Config. no. 11	Config. no. 12	Config. no. 8	Config. no. 1
A Forma de Gobierno	A2 Gobierno sin poder de decisión y sin visión		A2 Gobierno sin poder de decisión y sin visión			A2 Gobierno sin poder de decisión y sin visión	A1 Gobierno con poder de decisión y con visión	
H Gestión de las cuencas hidrográficas	H2 Gestión de las cuencas sin integración		H1 Gestión de las cuencas con integración	H2 Gestión de las cuencas sin integración		H1 Gestión de las cuencas con integración	H1 Gestión de las cuencas con integración	
B Gestión de la empresa de agua	B3 Empresa de agua dependiente del gobierno		B3 Empresa de agua dependiente del gobierno	B1 Empresa de agua privada		B1 Empresa de agua privada	B2 Empresa de agua con autonomía del gobierno	
C Tarifas de agua y saneamiento	C1 Tarifas de agua no sincerada		C1 Tarifas de agua no sincerada	C2 Tarifas de agua sincerada		C2 Tarifas de agua sincerada	C2 Tarifas de agua sincerada	
D Demografía	D1 Crecimiento de la población alto		D1 Crecimiento de la población alto			D1 Crecimiento de la población alto	D3 LCrecimiento de la población bajo	
I Forma de desarrollo urbano	I2 Ciudad sin planificación y pocas áreas verdes		I2 Ciudad sin planificación y pocas áreas verdes			I2 Ciudad sin planificación y pocas áreas verdes	I1 Ciudad con planificación y áreas verdes	
E Pobreza urbana	E1 Pobreza urbana aumenta		E1 Pobreza urbana aumenta			E1 Pobreza urbana aumenta	E3 Pobreza urbana disminuye	
J Cobertura en la red de agua	J1 Cobertura de agua disminuye		J1 Cobertura de agua disminuye			J2 Cobertura de agua se mantiene	J3 Cobertura de agua aumenta	
F Consumo de agua per cápita	F3 Consumo per cápita de agua disminuye		F3 Consumo per cápita de agua disminuye			F3 Consumo per cápita de agua disminuye	F3 Consumo per cápita de agua disminuye	
G Pérdidas en la red	G1 Pérdidas de agua aumentan		G1 Pérdidas de agua aumentan			G1 Pérdidas de agua aumentan	G2 Pérdidas de agua disminuyen	
K Tratamiento y reuso de aguas residuales	K1 Tratamiento y reuso de aa.rr. se mantiene		K1 Tratamiento y reuso de aa.rr. se mantiene		K2 Tratamiento y reuso de aa.rr. aumenta	K2 Tratamiento y reuso de aa.rr. aumenta	K2 Tratamiento y reuso de aa.rr. aumenta	
L Fuentes de agua por infraestructura	L3 Fuentes de agua disminuyen		L1 Fuentes de agua aumentan	L2 Fuentes de agua se mantienen	L3 Fuentes de agua disminuyen	L1 Fuentes de agua aumentan	L1 Fuentes de agua aumentan	
M Cambio climático (caudal y riesgos)	M3 Caudal bajo (sequías graves)	M1 Caudal de los ríos excesivo (inundaciones)	M3 Caudal de los ríos bajo (sequías graves)	M1 Caudal de los ríos excesivo (inundaciones)	M3 Caudal de los ríos bajo (sequías graves)	M3 Caudal de los ríos bajo (sequías graves)	M3 Caudal bajo (sequías graves)	M2 Caudal de los ríos aumenta sin riesgos

Annex EE Second simplification of the scenario sample, n= 7 configurations (Lima Water)

Version ‘integration’, before iteration.

	Escenario A: Condiciones climáticas difíciles se suman a una gobernanza muy deficiente		**Escenario B: La tragedia de las medidas aisladas**		**Escenario C: Las oportunidades de los actores al nivel meso**	**Escenario D: Resiliencia al clima por medio de la gobernanza**	
			Escenario B1: La gestión de cuencas nadando contracorriente	**Escenario B2: La empresa de agua privada como luchador solitario**			
	Config. no. 10	**Config. no. 3**	Config. no. 9	Config. no. 11	Config. no. 12	Config. no. 8	Config. no. 1
A Forma de Gobierno	A2 Gobierno sin poder de decisión y sin visión		A2 Gobierno sin poder de decisión y sin visión		A2 Gobierno sin poder de decisión y sin visión	A1 Gobierno con poder de decisión y con visión	
H Gestión de las cuencas hidrográficas	H2 Gestión de las cuencas sin integración		H1 Gestión de las cuencas con integración	H2 Gestión de las cuencas sin integración	H1 Gestión de las cuencas con integración	H1 Gestión de las cuencas con integración	
B Gestión de la empresa de agua	B3 Empresa de agua dependiente del gobierno		B3 Empresa de agua dependiente del gobierno	B1 Empresa de agua privada	B1 Empresa de agua privada	B2 Empresa de agua con autonomía del gobierno	
C Tarifas de agua y saneamiento	C1 Tarifas de agua no sincerada		C1 Tarifas de agua no sincerada	C2 Tarifas de agua sincerada	C2 Tarifas de agua sincerada	C2 Tarifas de agua sincerada	
D Demografía	D1 Crecimiento de la población alto		D1 Crecimiento de la población alto		D1 Crecimiento de la población alto	D3 LCrecimiento de la población bajo	
I Forma de desarrollo urbano	I2 Ciudad sin planificación y pocas áreas verdes		I2 Ciudad sin planificación y pocas áreas verdes		I2 Ciudad sin planificación y pocas áreas verdes	I1 Ciudad con planificación y áreas verdes	
E Pobreza urbana	E1 Pobreza urbana aumenta		E1 Pobreza urbana aumenta		E1 Pobreza urbana aumenta	E3 Pobreza urbana disminuye	
J Cobertura en la red de agua	J1 Cobertura de agua disminuye		J1 Cobertura de agua disminuye		J2 Cobertura de agua se mantiene	J3 Cobertura de agua aumenta	
F Consumo de agua per cápita	F3 Consumo per cápita de agua disminuye		F3 Consumo per cápita de agua disminuye		F3 Consumo per cápita de agua disminuye	F3 Consumo per cápita de agua disminuye	
G Pérdidas en la red	G1 Pérdidas de agua aumentan		G1 Pérdidas de agua aumentan		G1 Pérdidas de agua aumentan	G2 Pérdidas de agua disminuyen	
K Tratamiento y reuso de aguas residuales	K1 Tratamiento y reuso de aa.rr. se mantiene		K1 Tratamiento y reuso de aa.rr. se mantiene	K2 Tratamiento y reuso de aa.rr. aumenta	K2 Tratamiento y reuso de aa.rr. aumenta	K2 Tratamiento y reuso de aa.rr. aumenta	
L Fuentes de agua por infraestructura	L3 Fuentes de agua disminuyen		L1 Fuentes de agua aumentan	L3 Fuentes de agua disminuyen	L1 Fuentes de agua aumentan	L1 Fuentes de agua aumentan	
M Cambio climático (caudal y riesgos)	M3 Caudal bajo (sequías graves)	M1 Caudal de los ríos excesivo (inundaciones)	M3 Caudal de los ríos bajo (sequías graves)		M3 Caudal de los ríos bajo (sequías graves)	M3 Caudal bajo (sequías graves)	M2 Caudal de los ríos aumenta sin riesgos
Escenario de referencia	**A/'seco”**	Alternativa A/ 'húmedo'	**B1**	**B2**	**C**	**D/ 'seco'**	Alternativa D/'húmedo'

Annex FF Final scenario sample (Lima Water)

Version 'iteration', i.e. final version after the change of scenario C in Mai 2013. Changes marked in dark grey boxers and white, bold type.

	Escenario A: Condiciones climáticas difíciles se suman a una gobernanza muy deficiente		**Escenario B: La tragedia de las medidas aisladas**		**Escenario C: Las oportunidades de los actores al nivel meso**	**Escenario D: Resiliencia al clima por medio de la gobernanza**	
			Escenario B1: La gestión de cuencas nadando contracorriente	**Escenario B2: La empresa de agua privada como luchador solitario**			
	Config. no. 10	**Config. no. 3**	Config. no. 9	Config. no. 11	/	Config. no. 8	Config. no. 1
A Forma de Gobierno	A2 Gobierno sin poder de decisión y sin visión		A2 Gobierno sin poder de decisión y sin visión		A2 Gobierno sin poder de decisión y sin visión	A1 Gobierno con poder de decisión y con visión	
H Gestión de las cuencas hidrográficas	H2 Gestión de las cuencas sin integración		H1 Gestión de las cuencas con integración	H2 Gestión de las cuencas sin integración	H1 Gestión de las cuencas con integración	H1 Gestión de las cuencas con integración	
B Gestión de la empresa de agua	B3 Empresa de agua dependiente del gobierno		B3 Empresa de agua dependiente del gobierno	B1 Empresa de agua privada	B1 Empresa de agua privada	B2 Empresa de agua con autonomía del gobierno	
C Tarifas de agua y saneamiento	C1 Tarifas de agua no sincerada		C1 Tarifas de agua no sincerada	C2 Tarifas de agua sincerada	C2 Tarifas de agua sincerada	C2 Tarifas de agua sincerada	
D Demografía	D1 Crecimiento de la población alto		D1 Crecimiento de la población alto		**D1 Crecimiento de la población medio**	D3 LCrecimiento de la población bajo	
I Forma de desarrollo urbano	I2 Ciudad sin planificación y pocas áreas verdes		I2 Ciudad sin planificación y pocas áreas verdes		I2 Ciudad sin planificación y pocas áreas verdes	I1 Ciudad con planificación y áreas verdes	
E Pobreza urbana	E1 Pobreza urbana aumenta		E1 Pobreza urbana aumenta		**E1 Pobreza urbana se mantiene**	E3 Pobreza urbana disminuye	
J Cobertura en la red de agua	J1 Cobertura de agua disminuye		J1 Cobertura de agua disminuye		J2 Cobertura de agua se mantiene	J3 Cobertura de agua aumenta	
F Consumo de agua per cápita	F3 Consumo per cápita de agua disminuye		F3 Consumo per cápita de agua disminuye		F3 Consumo per cápita de agua disminuye	F3 Consumo per cápita de agua disminuye	
G Pérdidas en la red	G1 Pérdidas de agua aumentan		G1 Pérdidas de agua aumentan		G1 Pérdidas de agua aumentan	G2 Pérdidas de agua disminuyen	
K Tratamiento y reuso de aguas residuales	K1 Tratamiento y reuso de aa.rr. se mantiene		K1 Tratamiento y reuso de aa.rr. se mantiene	K2 Tratamiento y reuso de aa.rr. aumenta	K2 Tratamiento y reuso de aa.rr. aumenta	K2 Tratamiento y reuso de aa.rr. aumenta	
L Fuentes de agua por infraestructura	L3 Fuentes de agua disminuyen		L1 Fuentes de agua aumentan	L3 Fuentes de agua disminuyen	L1 Fuentes de agua aumentan	L1 Fuentes de agua aumentan	
M Cambio climático (caudal y riesgos)	M3 Caudal bajo (sequías graves)	M1 Caudal de los ríos excesivo (inundaciones)	M3 Caudal de los ríos bajo (sequías graves)		M3 Caudal de los ríos bajo (sequías graves)	M3 Caudal bajo (sequías graves)	M2 Caudal de los ríos aumenta sin riesgos
Escenario de referencia	**A/'seco"**	Alternativa A/ 'húmedo'	**B1**	**B2**	**C**	**D/ 'seco'**	Alternativa D/'húmedo'

Annex GG Example for the *ScenarioWizard* protocol and impact diagrams (Lima Water)

(Source; Influences on the scenario element G *water network losses,* variant G1 *increasing water network losses* in scenario C (config 12), Screenshot of the automatic *SzenarioWizard* output, matrix No. 10)

Kommentar

Einfluss des Deskriptors 'D Demography': With a higher population growthwater losses tend to increase. On one hand this is because of the increasing amount of illegal connections (apparent losses) and on the other hand because of technical reasons, as longer networks seem to lose more water (physical losses).

Einfluss des Deskriptors 'E Urban poverty': With higher poverty indexes the illegal connections tend to rise and therefore apparent water losses increase, for the same reason (illegal connections tend to diminish) water losses decrease if poverty decreases.

Einfluss des Deskriptors 'I Form of urban development': With a disorganized territorial development water and sewerage network tends to be in bad condition, generating increasing physical losses. Furthermore illegal connections tend to increase,which lets also increase the apparent losses.

Für den Deskriptor 'G Water network losses' ist 'G1 Increasing water network losses' angenommen. Für diese Annahme sprechen folgende Szenario-Elemente:

- D Demography: D1 High population growth (Gewicht 2)
- E Urban poverty: E1 Increasing poverty (Gewicht 2)
- I Form of urban development: I2 City without uban planning and with few green areas (Gewicht 1)

Gegen diese Annahme sprechen folgende Szenario-Elemente:

- B Form of water company: B1 Private (Gewicht -2)
- C Water and wastewater tariffs: C2 Cost-covering tariffs (Gewicht -1)

Damit ergibt sich für diese Annahme eine Impact-Bilanz von + 2. Es überwiegen also die Argumente für diese Annahme.

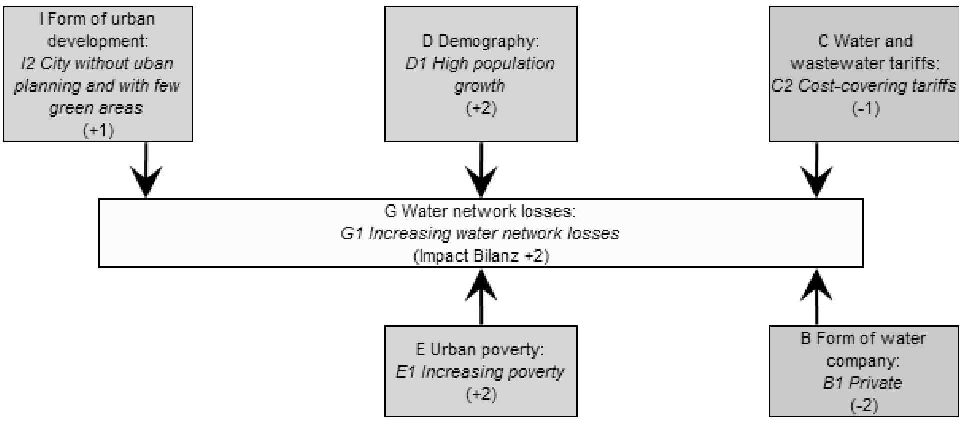


Abb. 7: Einflüsse auf das Szenario-Element 'G Water network losses: G1 Increasing water network losses'.

Annex HH Expample for an input data sheet for LiWatool scenario simulations (excerpt) (Lima Water)

Source: DOC Scenarioquantification 20130313, excerpt.

	A	B	C	D	E	F	G	H	I	J	
10	**Szenario A**	x			x			x			
11	**Szenario B1**	x			x			x			
12	**Szenario B2**		x		x			x			
13	**Szenario C**		x		x			x			
14	**Szenario D**		x				x			x	
15	Deskriptortx	no sincerada	sincerada		high	medium	low	poverty incr.		pov. Decreas	cons
16	Unit	PEN/m3	PEN/m3		Population	Population	Population	NSE (D+E)	NSE (D+E)	NSE (D+E)	
17	Deskriptor	C1	C2		D1	D2	D3	E1	E2	E3	F1
18	Block name	_GLOBAL	_GLOBAL		_GLOBAL	_GLOBAL	_GLOBAL	Lima y Callac	Lima y Callac	Lima y Callac	_GLC
19	Parameterna	PENm3	PENm3		Poblacion	Poblacion	Poblacion	pctnivelD	pctnivelD	pctnivelD	savfa
20	2007	2,117	2,117		8.482.619	8.482.619	8.482.619	40,30	40,30	40,30	
21	2008	2,138	2,138		8.609.376	8.609.376	8.609.376	40,30	40,30	40,30	
22	2009	2,160	2,160		8.737.949	8.737.949	8.737.949	40,30	40,30	40,30	
23	2010	2,182	2,182		8.871.450	8.871.450	8.871.450	40,30	40,30	40,30	
24	2011	2,203	2,203		9.010.331	9.010.331	9.010.331	40,30	40,30	40,30	
25	2012	2,225	2,225		9.152.498	9.152.498	9.152.498	40,30	40,30	40,30	
26	2013	2,248	2,292		9.297.310	9.297.310	9.297.310	40,30	40,30	40,30	1,00
27	2014	2,270	2,361		9.444.132	9.444.132	9.444.132	40,30	40,30	40,30	1,00
28	2015	2,293	2,432		9.592.315	9.592.315	9.592.315	40,30	40,30	40,30	1,01
29	2016	2,316	2,505		9.784.162	9.736.200	9.717.015	40,744	40,30	39,494	1,01
30	2017	2,339	2,580		9.979.845	9.882.243	9.823.903	41,188	40,30	38,688	1,01
31	2018	2,362	2,657		10.179.442	10.030.477	9.931.966	41,632	40,30	37,882	1,02
32	2019	2,386	2,737		10.383.031	10.180.934	10.041.217	42,076	40,30	37,076	
33	2020	2,410	2,819		10.590.691	10.333.648	10.151.671	42,52	40,30	36,27	1,02
34	2021	2,434	2,904		10.802.505	10.488.653	10.263.339	42,964	40,30	35,464	1,03

Tabelle1 | Grafiken NSE | Grafiken Poblacion | perdidas | Rios, tarifas

Markieren Sie den Zielbereich, und drücken Sie die Eingabetaste.

Annex II Matching: Overview on final translation of qualitative descriptor variants into indicators and time-series (Lima Water)

Own representation based on DOC Scenarioquantification 20150502.

Descriptor	Variant	Corresponding input parameter name	Indicator (base year: value)	Value assumed for 2040 (TS 02. 05. 2013 "simulation final brochure")
C Tarifas de agua y saneamiento (conectados)	C1 Tarifa de agua no sincerada	Tarifas (promedio)	PEN/m3 (2011: 2,20)	2,94
	C2 Tarifa de agua sincerada			5,092
D Demografía	D1 Crecimiento de la población alto	Population	Inhabitants (2011: 9,010,331)	15,737,210
	D2 Crecimiento de la población medio			13,592,497
	D3 Crecimiento de la población bajo			11,532,565
E Pobreza urbana	E1 Pobreza incrementa	Poverty: NSE (D+E) (niveles socioeconómicos)	Percentage of population belonging to social levels NSE (2011: D&E: 40,3 C: 37,1 B: 17,5 A: 5,1)	D&E: 45 C: 35 B: 10 A: 10
	E2 Pobreza se mantiene			D&E: 40,3 C: 37,1 B: 17,5 A: 5,1
	E3 Pobreza disminuye			D&E:30 C: 45 B: 20 A: 5
F Consumo de agua per cápita	F1 Consumo per cápita aumenta	_GLOBAL savfactor0	Percentage of drinking water saved (2011: 1)	1,1
	F2 Consumo per cápita igual			1
	F3 Consumo per cápita disminuye			0,9
G Pérdidas de agua en la red (incl. conex.cland.)	G1 Pérdidas de agua aumentan	ANF	% de ANF (Agua no facturada) (2011: 34,58)	40
	G2 Pérdidas de agua disminuyen			25
I Forma de desarrollo urbano	I1 Ciudad con protección de valles y áreas verdes	SPLIT into three: Areas Agricultura: Aagric; Areas verdes: Averde_porpersona Areas verdes: CPQ_Averde	(2011: Urban agriculture: ha (2011: 13,600) public green area: M2/capita (2011: 3,9) Water demand of public green: m3/m2/year (2011: 1,49)	Agagric: 8000ha 5 m3/capita CPQ: 1,3
	I2 Ciudad sin planificación y con pocas áreas verdes			Agagric: 8000ha 3 m3/capita CPQ: 1,49
J Cobertura de agua a la red pública	J1 Cobertura disminuye	pctpotable	Porcentaje de la población con acceso a agua proveniente de la red pública en % (per cápita) (2011: 89)	85
	J2 Cobertura se mantiene			89
	J3 Cobertura aumenta			98
K Tratamiento y reuso de aguas residuales	K1 Tratamiento al 95% con reutilización de 5%	PTARs_secundarias: Qmax *(Tratamiento secondario)* Efluente PTARs: factorreuso *(Reuse*	*M3/s* *(2011: 2,8)* *Percentage* de de aguas residuales tratadas	*2,8 m3/s* *26,75%*
	K2 Tratamiento al 95% con reutilización de 20 a 40%			5,6 m3/s *80%*

Descriptor	**Variant**	**Corresponding input parameter name**	**Indicator** (base year: value)	**Value assumed for 2040 (TS 02. 05. 2013 “simulation final brochure”)**
		for irrigation)	(tratamiento secundario) disponibles para el riego *(2011: 26,75)*	
L Fuentes de agua disponibles	L1 Fuentes de agua aumentan	Pozos aguas: Qmax (Groundwater)	M3/s (2011: 345600)	345600 (constant)
	L2 Fuentes de agua como en 2010			345600 (constant)
	L3 Fuentes de agua disminuyen			172800 (minus 50%)
M Cambio climático (caudal de agua y riesgo)	M1 Caudal excesivo (inundaciones)	Rio Rimac: Qriver; Rio Chillon: Qriver; Rio Lurin: Qriver	M3/s (2011: Rimac: 2090016 Chillon: 440640 Lurin: 388800)	Rimac: +6% Chillon: +6% Lurin: +6%
	M2 Caudal se incrementa sin riesgos			Rimac: +6% Chillon: +6% Lurin: +6%
	M3 Caudal bajo (sequía grave)			Rimac: - 13,27% Chillon: -12,08% Lurin: -10.59%

Annex JJ Scenario structure: Consistency between the structure of storylines and the structure of the raw CIB scenarios (Lima Water)

See Supplement C_CIB vs. storylines over time Lima Water, own assessments.

	Long version	**Short version**	**Narrative part of integrated brochure V1 Integration (March 2012)**	**Narrative part of integrated brochure V2 Iteration (Mai 2012)**
Reference table (scenario sample)	***First Scenario table autumn 2011 n= 16 CIB configurations (indicating n= 8 CIB reference configurations)***	***Scenario table March 2012 n= 8 CIB reference configurations (first simplification)***	***Scenario table March 2013 n=7 CIB reference configurations) second simplification)***	***Final Scenario table Mai 2013 n=6 reference configurations PLUS: Scenario C changed independently of CIB matrix***
Type of reference to CIB configurations	Text makes explicit reference to configurations in footnotes, tables included into each storyline text. Storyline texts are *explicitly* based on configurations and have been *checked* through comparison of content.	Text version makes no direct reference to configurations, but table included to the same document- behind text of all four storylines. Basis of text on configurations is *assumed* and *checked* through comparison of content (see below).	text version makes no direct reference to configurations, but table included to the same document- before the presentation of the combined scenarios. Basis of text on configurations is *assumed* and *checked* through comparison of content (see below).	text version makes no direct reference to configurations, but table included to the same document- before the presentation of the combined scenarios. Basis of text on configurations is *assumed* and *checked* through comparison of content (see below).
Scenario A	CIB config 3 (wet climate change) CIB config. 10 (dry climate change	CIB config 3 (wet climate change) CIB config. 10 (dry climate change	CIB config. 10 (dry climate change) Plus CIB config. 3 (wet climage change)	CIB config. 10 (dry climate change) Plus CIB config. 3 (wet climage change)
Scenario B1	CIB config. 9 Variant corresponding to config 13 included	Text integrating B1 and B2, assumedly overall based on config 11 that is assuming increasing levels of waste water treatment (assumption that is a slight impreci-sions with regard to B1). Integrated Variant B1 corresponding to Config 9, Integrated ariant B2 vaguely comprising configurations 14 and 11.	CIB config. 9	CIB config. 9
Scenario B2	CIB config.11 Variants corresponding config.s 4, 7 and 5 included		CIB config.11	CIB config.11
Scenario C	CIB config. 12 Variants corresponding to configs 14, 15 and 16 included	CIB config. 12	CIB config. 12	! New definition of scenario C, no CIB config.
Scenario D	CIB config. 8 (dry climate change) Config. 1 (wet climate change)	CIB config. 8 (dry climate change) Config. 1 (wet climate change)	CIB config. 8 (dry climate change) Plus CIB config, 1 (wet climate change)	CIB config. 8 (dry climate change) Plus CIB config, 1 (wet climate change)
Overall sample structure	Consistent	Consistent	Consistent with CIB scenario and sample structure	Consistent for scenarios A, B1, B2 and D, *inconsistent with regard to scenario C*

Annex KK Scenario <u>content</u>: Consistency of storyline texts with raw CIB scenarios (regarding descriptions of D&V and impacts) (Lima Water)

See Supplement C_CIB vs. storylines over time Lima Water, own assessments.
Legend: C = consistent with formulations of the CIB raw scenarios, IC= inconsistent, *<u>italic and underlined: inconsistent elements</u>*

Descriptor	Long version	Short version	Narrative part of integrated brochure V1 Integration (March 2012)	Narrative part of integrated brochure V2 Iteration (Mai 2012)
A Forma de Gobierno	C	*<u>For A1, policies for employment and against poverty have been included by the Peruvian stakeholders</u>* otherwise : C	See short version	See short version
B Modelo de Gestión de la Empresa de AyS	C	C	B1: some of the impacts logic of variant and scenario roughly described B3: *<u>impact of new issue of conflicts and contamination of water (cf. descriptor H) that are increasing costs of water company is added to the variant is a new impact going beyond the matrix!;</u>* otherwise: C	See 'Integration'
C Tarifas de agua y saneamiento (conectados)	C	C	In long and short version: "C1 no sincerada" means: do not cover operation and investment costs – in integrated version is only stated that they do not include environmental costs. (*<u>BUT even the "C2 sincerada", described in integrated version as 'allows considerable investments' does not do so, see descriptor essay!) IC .</u>*	See 'Integration'
D Demografía	C	C	C	C (*But change of numbers*) *<u>Old and new scenario C "ha aumentado" = C with crescimiento medio" (but specified through correct numbers)</u>*
E Pobreza urbana	C Poverty is defined on the basis of "Necesidades Básicas Insatisfechas"	C (very short)	*<u>IC: Takeover of poverty indicator used by LiWatool „social levels", that is far broader than the initially used one and goes beyond poverty by including more people.</u>* C: E3: Policies to reduce poverty are added as conditions for sinking poverty (C with addition to descriptor A and consistent with impacts stored in the matrix from descriptor A on E).	See 'Integration' (*but change of numbers)*
F Consumo de agua per cápita[441]	C	C C2: higher tariffs as a reason for sinking consumption per capita are newly mentioned, C with impacts stored in matrix	C See short version *<u>(exception: not only domestic water consumption is described but overall consumption (domestic and non-domestic and for irrigation).</u>*	C See short version (i.e. domestic water consumption only)
G Pérdidas de agua en la red (incl. conex.cland.)	C	C	Definition of water losses has become more precise over time, influenced by the numerical indicator ANF, two aspects of the losses are finally explicitly named in the final version:	See 'Integration'

441 Consumo is sinking across scenarios, but for different reasons, this logic has survived the storyline writing.

Descriptor	Long version	Short version	Narrative part of integrated brochure V1 Integration (March 2012)	Narrative part of integrated brochure V2 Iteration (Mai 2012)
			technical losses as well as illegal connections - the later ones had not been explicitly stated in the two earlier text versions, C with CIB matrix.	
H Modelo de gestión de las cuencas	C	No description of H1 in scenario D! H2 = C	H1: New and more precise (and more locally anchored) definition giving more detail to this descriptor; ideas= C H2: *Newly added aspect: issues of conflict and contamination of water in catchments has been added to this variant of the descriptor. This new aspect is assumed to have impacts on the water company (increasing costs, an impact going beyond the impacts stored in the matrix* [442]:	See 'Integration'
I Forma de desarrollo urbano	C	Description has been strongly extended and became more precise (refinement), consistent with initial ideas C	1: See short version, C I2: Including explicit impact between urban development and difficult extension of coverage of the network =C	See 'Integration' (*but change of numbers)*
J Cobertura de agua a la red pública	C	C	C	C
K Tratamiento y reuso de aguas residuales	C	Little details, very rough, otherwise = C	With comparable details as long version, but: more concise *= C*	See 'Integration' *but change of numbers)*
L Fuentes de agua disponibles	C	L1: No description in scenario D L2: No information on ground water.	L1: C with long version, reservoir lakes Marca II and V have been included as "extra measures", thus: C with CIB and with long version	See 'Integration' *but change of numbers)*
M Cambio climático (caudal de agua y riesgo)	C with regard to uncertainty of climate change. Poor information on risk and vulnerability	C with regard to uncertainty of Climte change condensed into occurrence of La Nina and el Nino phenomena. Plus: risks and vulnerability have been transformed into pressure of population on water management, i.e. consistent with impacts of M on H stored in the matrix. Scenario C: Under condition of drought: new elements of food insecurity added	C with regard to uncertainty of CC PLUs: risks and vulnerability have been transformed into / deduced to pressure of population on water management (consistent with impacts of M on H stored in Matrix) Scenario C: under condition of drought: issue of food insecurity slightly changed: "dependencia de alimentos importados"	See 'Integration' *but change of numbers)*

[442] In the years 2011 and 2012, there has been much debate and media coverage regarding these conflicts in Peru (e. g. "Conga gold mining"), i.e. the descriptor understanding seems adapted to current events.

Annex LL Summary: Apparent consistency between storylines/ narrative parts and raw CIB scenarios (Lima Water)

See Supplement C_CIB vs. storylines over time Lima Water, own assessments.
Legend: C= consistent, IC= inconsistent, *inconsistent elements in italic type and underlined*

	Consistency between (comparison with raw CIB scenarios)			
	Structure		Content	
	Indi. scenarios' structure	Sample structure	D&V	Interrelations
Long version	C	C	C (lacks some precision)	Rather silent
Short version	C, summing up some descriptors	C	C but some additional elements	Rather silent
V1 "Integration"	C	C	C except for • Poverty expressed by numerical indicator NSE only. • Definition of tariffs vague. • *Error with regard to definition of 'consumo'.*	A few made explicit, simplified logic.
V2 "Iteration"	C, except for scenario C	C, except for scenario C	C except for • Poverty expressed by numerical indicator NSE only. • Definition of tariffs vague.	A few made explicit, simplified logic.
Overall	Apparently consistent with structure of raw CIB scenario configurations (except for scenario C in V2). Short versions summing up some descriptors.	Consistent with CIB reference scenario samples over time (except for scenario C in V2).	Overall (rather) apparently consistent with raw CIB scenarios, lacking some precision in definitions. Adding some new elements but which are not necessarily contradicting. Some definitions slightly changed.	Mostly not described in storylines. ➔It is not possible to compare the mental models of writer with the matrix.

Annex MM Scenario <u>structure</u>: Consistency of input data sets and raw CIB scenarios (Lima Water)

See Supplement D_CIB vs. input data over time Lima Water, own assessments.
Legend: *inconsistent elements in italic type and underlined*

	13.03.2012 TS simulation 1	**06.12.2012 TS loop II**	**18.03.2013 TS integration**	**02.05.2013 TS iteration**
Reference table (reference sample structure)	***Scenario table March 2012 n= 8 CIB reference configurations***	***Scenario table March 2012 n= 8 n= 8 CIB reference configurations***	***Scenario table March 2013 n=7 CIB reference configurations***	***Scenario table Mai 2013 n=6 reference configurations PLUS:*** ***<u>Scenario C changed independently of CIB matrix</u>***
Scenario A	CIB config. 10 (*<u>dry climate change only)</u>* *<u>Save – factor applied</u>*	CIB config. 10 *<u>(dry climate change)</u>* *<u>Save – factor applied</u>*	CIB config. 10 (dry climate change) Plus CIB config. 3 (wet climage change) Save factor NOT applied	CIB config. 10 (dry climate change) Plus CIB config. 3 (wet climage change) Save factor NOT applied
Scenario B1	CIB config. 9 *<u>Save – factor applied</u>*	CIB config. 9 *<u>Save – factor applied</u>*	CIB config. 9 Save factor NOT applied	CIB config. 9 Save factor NOT applied
Scenario B2	CIB config.11 and 4 *<u>mixed:</u>* *<u>Error: reference scenario B2 (config 11) assumes dry climate change M3</u>* Save – factor applied	CIB config.11and 4 *<u>mixed:</u>* *<u>Error: scenario B2 (config 11) assumes dry climate change M3</u>* Save – factor applied	CIB config.11 *Error corrected, reduction of scenario table to <u>one</u>* <u>references config. 11</u> Save factor NOT applied	CIB config.11 Save factor NOT applied
Scenario C	CIB config. 12 Save – factor applied	CIB config. 12 Save – factor applied	CIB config. 12 Save – factor applied	*<u>New definition of scenario C, no CIB config.</u>* Save – factor applied
Scenario D	CIB config. 8 *<u>(dry climate change only)</u>* Save – factor applied	CIB config. 8 *<u>(dry climate change only)</u>* Save – factor applied	CIB config. 8 (dry climate change) Plus CIB config, 1 (wet climate change) Save – factor applied	CIB config. 8 (dry climate change) Plus CIB config, 1 (wet climate change) Save – factor applied
Overall scenario and sample structure	Rather consistent except for inconsistencies: a) Ambiguity of reference scenarios. b) Errors a and simplifications with regard to climate change assumptions. a) Formally correct but logically contradictory assumption of water savings.	Rather consistent except for inconsistencies: a) Ambiguity of reference scenarios. b) Errors a and simplifications with regard to climate change assumptions. c) Formally correct but logically contradictory assumption of water savings.	Consistent	Consistent except for scenario structure of input data representing scenario C, not based on internally consistent CIB configuration

Annex NN Scenario <u>content</u>: Apparent consistency between and CIB descriptors and numerical indicators (Lima Water)

See Supplement D_CIB vs. input data over time Lima Water, own assessments.
Legend: grey boxes= potential threat to consistency; dark grey boxes = threat to consistency; *changes over time indicated in italic type*

Qualitative descriptors	Versions of input data over time				Assessment		
	13.03.2012 "TS simulation 1"	**06.12.2012 "TS loop II"**	**18.03.2013 "TS integration"**	**02.05.2013 "TS iteration"**	**Split into more than one TS?**	**'Match': Partial? Full? Larger?**	**Apparent consistency?**
A Form of government							
B Form of water company							
C Tarifas de agua y saneamiento (connectados)	PEN/ M3	PEN/ M3	PEN/ M3	PEN/m3	No	Partial: investment and operation costs covered only (evironmental costs not considered).	Consistent
D Demografía	Inhabitants	Inhabitants	Inhabitants	Inhabitants	No	Full	Consistent
E Pobreza urbana	Percentage of population belonging to socio-economic levels NSE: A-C D&E	Percentage of population belonging to socio-economic levels NSE: A-C D&E	Percentage of population belonging to socio-economic levels NSE: *A* *B* *C* *D&E*	Percentage of population belonging to socio-economic levels NSE: *A* *B* *C* *D&E*	First into 2 than into 4 socio-economic groups.	Indicator larger than descriptor.	Does not match well.
F Consumo de agua per cápita	Percentage of drinking water saved (Save factor)	Percentage of drinking water saved (Save factor)	Percentage of drinking water saved (Save factor)	Percentage of drinking water saved (Save factor)	save factor (input) and consumption: model output!	Very partial (consumption itself is model output)	Translated part consistent
G Pérdidas de agua en la red (incl. conex.cland.)	% de ANF (Agua no facturada)	% de ANF (Agua no facturada)	% de ANF (Agua no facturada)	% de ANF (Agua no facturada)	No	Full	Consistent
H Catchment management							
I Forma de desarrollo urbano	Water demand parks and agriculture (l/s)	*Green area parks (ha)* *Green area agriculture* (ha)	Urban agriculture: ha *public green area: M2/capita;* *Water demand of public*	Urban agriculture: ha public green area: M2/capita; Water demand of public	Over time split into finally 3 indicators	Partial, covering aspect of green area only	Translated part: C

Qualitative descriptors	Versions of input data over time				Assessment		
	13.03.2012 "TS simulation 1"	06.12.2012 "TS loop II"	18.03.2013 "TS integration"	02.05.2013 "TS iteration"	Split into more than one TS?	'Match': Partial? Full? Larger?	Apparent consistency?
			green: m3/m2/year	green: m3/m2/year			
J Cobertura de agua a la red pública	Percentage of population with access to drinking water provided by the public water network in % (per capita).	Percentage of population with access to drinking water provided by the public water network in % (per capita).	Percentage of population with access to drinking water provided by the public water network in % (per capita).	Percentage of population with access to drinking water provided by the public water network in % (per capita).	No	Full	Consistent
K Tratamiento y reuso de aguas residuales	% of wastewater for any type of WWTP % of wastewater for secondary treatment of all wastewaters for treatment	*Primary treatment assumed to be constant* *Secondary treatment: M3/s* *Treated wastewater available for irrigation: %*	Primary treatment assumed to be constant). Secondary treatment: M3/s Treated wastewater available for irrigation: *%*	Primary treatment assumed to be constant). Secondary treatment: M3/s Treated wastewater available for irrigation: *%*	Split into different levels of treatment and percentage of reuse	Full	Consistent
L Fuentes de agua disponibles	Combined: Groundwater m3/d River water (rio Rimac) arriving at drinking water preparation plant Atarchea m3/d (Rimac) Water arriving by Chillon m3/d	Combined: Groundwater m3/d River water (rio Rimac) arriving at drinking water preparation plant Atarchea m3/d (Rimac) Water arriving by Chillon m3/d	Groundwater *M3/s*	Groundwater M3/s	No	Partial, groundwater only	Translated part consistent.
M Cambio climático (caudal de agua y riesgo)			*River runoffs:* *Rimac, M3/s* *Chillon M3/s*	River runoffs: Rimac, M3/s Chillon M3/s *Lurin M3/s*	Split into runoff of two (three) different rivers providing water to the city	Partial, only river runoff	Translated part consistent
Overall: indicators consistent?	Translated descriptor (parts) consistent, except NSE for poverty.	Translated descriptor (parts) consistent, except NSE for poverty. Further specification of I and K.	Translated descriptor (parts) consistent, except NSE for poverty. Further specification of I , L and M.	Translated descriptor (parts) consistent, except NSE for poverty. Further specification of M.	5 out of 10 descriptors represented by **more than one indicator**	5 out of 10 indicators only **partial** representations of descriptors, one indicator 'larger' than descriptor (NSE)	Translated (parts) descriptors consistent, except for NSE for poverty

Annex OO Scenario content: Apparent consistency between direction and spread of input data and CIB variants (Lima Water)

See Supplement D_CIB vs. input data over time Lima Water, own assessments.
Legend: C= Consistent; grey boxes= potential threat to consistency*; changes over time indicated in italic type*.

Qualitative descriptors & variants	**Numerical value in 2040**	**Indicator**	**13.03.2012 " TS simulation 1"**	**06.12.2012 "TS loop II"**	**18.03.2013 "TS integration"**	**02.05.2013 "TS iteration"**	**Consistency of direction and spread over time?**
A Form of gov-ernment	A1 Government with decision power and vision A2 Government without decision power and vision		/	/	/	/	/
B Form of water company	B1 Private B2 Public with autonomy from the government B3 Public without autonomy from the government		/	/	/	/	/
C Tarifas de agua y saneamiento (connectados)	C1 Reduced (non cost-covering) tar-iffs C2 Cost-covering tariffs	PEN/m3	*4,02* *13,15*	*2,94* *5,40*	*2,94* *5,09*	2,94 5,09	Direction C Spread C (smaller over time).
D Demografía	D1 High population growth D3 Low population growth	Inhabitants	16305557 11263393	*15.737.210* *11.532.565*	15.737.210 11.532.565	15.737.210 11.532.565	Direction and spread: C
E Pobreza urbana	E1 Increasing poverty E3 Decreasing poverty	NSE (% of population D&E)	65,8 22	*71,1* *27,4*	*51,4* *20,15*	*45* *30*	Direction: C Spread considerably smaller over time
F Consumo de agua per cápita	F1 Increasing water consumption per capita F3 Decreasing water consumption per capita	Save factor	1,1 0,9	1,1 0,9	1,1 0,9	1,1 0,9	Direction and spread C
G Pérdidas de agua en la red (incl. conex.cland.)	G1 Increasing water network losses G2 Decreasing water network losses	*Factor* *(% of ANF, Agua no facturada)*	1,16 0,68	1,16 0,68	*1,33 (43)* *0,83 (25)*	*1,157 (40)* *0,72 (25)*	Direction and spread: C (smallest in latest version i.e. most opti-mistic numerical assumption for G1)

Qualitative descriptors & variants	Numerical value in 2040	Indicator	13.03.2012 “ TS simulation 1”	06.12.2012 “TS loop II”	18.03.2013 “TS integration”	02.05.2013 “TS iteration”	Consistency of direction and spread over time?
H Catchment management	H1 Integrated and participatory management H2 Management depending on the government without integration		/	/	/		/
I Forma de desarrollo urbano	I1 City with protection of valleys and green areas I2 City without urban planning and with few green areas	Urban agriculture: ha	15300 (constant)	*8000* *(constant)*	*3400* *2400*	*8000* *8000*	No variation in TS loop II and Iteration = IC? (albeit different argumentations, quantitity in H1 and H2= identical?) (changes of base year until last version).
		public green area: M2/capita;		*9573 ha* *5267 ha*	*5 m2/capita* *3 m2/capita*	*5 m2/capita* *3 m2/capita*	Direction and spread consistent.
		Water demand of public green: m3/m2/year	/	/	*1,3* *1,49*	1,3 1,49	Direction and spread consistent.
J Cobertura de agua a la red pública	J1 Decreasing coverage rate J3 Increasing coverage rate	population connected to network %	80 98	80 98	*75* 98	*85* 98	Direction: C, spread: finally rather very optimistic interpretation of J1 decreasing (status quo “iteration” 89%).
K Tratamiento y reuso de aguas residuales	K1 Treatment of 95% with reuse of 5% K2 Treatment of 95% with reuse of 20 to 40%	Secondary treatment: M3/s	17,89 % of WW 46,84 % of WW	*2,8* *2,8*	*2,8* *5,6*	2,8 5,6	direction and spread: consistent except for TS loop II.
		Treated wastewater available for irrigation: %	/	*29,4%* *100%*	*26,75* *80*	26,75 80	Direction: C, more cautious over time (also due to change of base year value), spread: C and also more cautious over time.

Numerical value in 2040 Qualitative descriptors & variants		Indicator	13.03.2012 " TS simulation 1"	06.12.2012 "TS loop II"	18.03.2013 "TS integration"	02.05.2013 "TS iteration"	Consistency of direction and spread over time?
L Fuentes de agua disponibles	L1 Increasing water supply L3 Decreasing water supply	*Groundwater m3/s* *(factor in earlier version)*	(See FN below[443]: factors for combinations of L and M: L1: (1,05) L3: (1)		*345600 (constant)* *172800 (-50%)*	345600 (constant) 172800 (-50%)	Increasing water supply through infrastructure assumes constant groundwater, as use beyond constant level would not be sustainable. IC at first sight, but in line with scenarios' logic.
M Cambio climático (caudal de agua y riesgo)	M1 Excessive water flow (flooding) M3 Low water flow (severe droughts)	*River runoffs: Rimac, M3/s*	M1: 1,15 M3: 0,9		*2215416,96* *1881014,4 (minus 10%)*	2215416,96 *1803265,8 (minus 13,72%)*	TS integration and iteration: direction and spread: C (M1 plus 6%,,M2 withdifferent assumptions per river).
		Chillon M3/s			*467078,4* *396576 (minus 10%)*	467078,4 *387410,7 (minus 12,08%)*	
		Lurin M3/s			/	*412128,0* *347626,1 (minus 10,6%)*	

443 Assumptions on factor used to calculate water amount in 2040 resulting out of combinations of L and M (source: DOC Scenarioquantification_20121206).

Factor:	**M1 (1,15)**	**M2 (1,1)**	**M3 (0,9)**
L1 (1,05)	1,2075	1,155	0,945
L 1 (1)	1,15	1,1	0,9
L3 (1)	1,15	1,1	0,9

Numerical value in 2040 Qualitative descriptors & variants	Indicator	13.03.2012 " TS simulation 1"	06.12.2012 "TS loop II"	18.03.2013 "TS integration"	02.05.2013 "TS iteration"	Consistency of direction and spread over time?
Overall: time-series consistent with CIB variants?		Direction and spread of TS consistent with variants, exception: I1 and I2 = assumed as identical and constant	*New split of I and K* Direction and spread of TS consistent with variants, exception I: urban agricultural area assumed constant, but consistent spread assumed for public green. K: % of secondary treatment assumed constant, but consistent spread assumed for part used for irrigation. Spread smaller than in earlier version for C and D.	*New split of I, L and M;* Direction and spread of all TS consistent with variants. Spread smaller than in earlier version for E, K (wastewater for irrigation) and L (increasing GW = constant groundwater). Spreader larger than in earlier version for D	*New split of M;* Direction and spread of TS consistent with variants: exception: I, urban agricultural area assumed constant Spread smaller than in earlier version for E, J. spreader larger than in earlier version for D, M (all 3 rivers albeit to different degrees).	Overall, TS became more specific and more split over time. Overall, TS are consistent in direction (all) and spread with variants. Several TS become more conservative in spread over time, as e. g.C (tariffs), E (poverty) or J (cobertura), some TS become larger in spread over time, e. g. M.

Annex PP Summary: Apparent consistency between input-data sets and raw CIB scenarios (Lima Water)

See Supplement D_CIB vs. input data over time Lima Water, own assessments

	Apparent consistency between (comparison with raw CIB scenarios)			
	Structure		**Content**	
	Indiv. scenarios' structure	**Sample structure**	**D&V**	**Interrelations**
TS first simulation	Rather consistent except for inconsistencies: • Ambiguity of reference scenarios. • Errors and simplifications with regard to climate change assumptions. • Formally correct but logically contradictory assumption of water savings.	Consistent with CIB table n=8	*Indicators*: Translated descriptor (parts) consistent, except NSE for poverty *Time-series*: Direction and spread of TS consistent with variants, exception: I1 and I2 = assumed as identical and constant	Assumptions on interrela-tion not visible in time-series – not made explicit in a systematic way – no com-parison with CIB possible.

TS 2 Loop III	Rather consistent except for inconsistencies:
	• Ambiguity of reference scenarios.
	• Errors a and simplifications with regard to climate change assumptions.
	• Formally correct but logically contradictory assumption of water savings.
		Consistent with CIB table n= 8	*Indicators*: Translated descriptor (parts) consistent, except NSE for poverty; Further specification of I and K.
			Time-series:
			• *New split of I and K.*
			• Direction and spread of TS consistent with variants, exception
			  ○ I: urban agricultural area assumed constant, but consistent spread assumed for public green
			  ○ K: % of secondary treatment assumed constant, but consistent spread assumed for part used for ir-rigation.
			  ○ *Spread* smaller than in earlier version for C and D.
				Assumptions on interrela-tion not visible in time-series – not made explicit in a systematic way – no com-parison with CIB possible.

TS 3 Inte-gration	Consistent	Consistent with CIB table n=7	*Indicators*: Translated descriptor (parts) consistent, except NSE for poverty; Further specification of I , L and M.
			Time-series:
			• *New split of I and M*.
			• Direction and spread of all TS consistent with variants.
			  ○ *spread* smaller than in earlier version for E, K (wastewater for irrigation).
			  ○ spreader larger than in earlier version for D.
				Assumptions on interrela-tion not visible in time-series – not made explicit in a systematic way – no com-parison with CIB possible.

TS 4 Itera-tion	Consistent except for scenario structure of input data representing scenario C, not based on inter-	Consistent with CIB table n= 6 and	*Indicators*: Translated descriptor (parts) consistent, except NSE for poverty;	Assumptions on interrela-tion not visible in time-

	Apparent consistency between (comparison with raw CIB scenarios)			
	Structure		Content	
	Indiv. scenarios' structure	Sample structure	D&V	Interrelations

	nally consistent CIB configuration.	with new scenario C.	Further specification of M
			Time-series:
			• *New split of M.*
			• Direction and spread of TS consistent with variants: exception: I, urban agricultural area assumed constant
			  ○ *Spread* smaller than in earlier version for E , J.
			  ○ Spreader larger than in earlier version for D, M (all 3 rivers albeit to different degrees).
				series – not made explicit in a systematic way – no comparison with CIB possible.

Overall	Indiv. input data sets are getting more consistent with CIB scenario structure over time, exception: scenario C version 'iteration'	Input data set samples correspond to CIB reference tables, exception scenario C version 'iteration'	**Indicators** (All input data sets): 10 out of 13 descriptors somehow quantified in form of input data/parameters. 5 out of 10 descriptors represented by more than one indicator. 5 out of 10 indicators only partial representations of descriptors, one indicator 'larger' than descriptor (NSE). Further specification (and split) of indicators over time. Overall, translated (parts of)descriptors consistent, except for NSE for poverty. **Time-series:** Overall, TS became more specific and more split over time. Overall, TS are consistent in direction (all) and spread with variants. Several TS become more conservative in spread over time, as e. g.C (tariffs), E (poverty) or J (cobertura), some TS become larger in spread over time, e. g. M.	Assumptions on interrelation not visible in time-series – not made explicit in a systematic way – no comparison with CIB possible.

Annex QQ Water consumption in LiWatool and CIB, definitions and calculations (Lima Water)

The CIB comprises the descriptor F "*domestic* water consumption per capita". LiWatool calculates several different outputs that are concerned with the water consumption, among others the "overall water consumption of the city". Among these, the most adequate point of comparison is, in my view, the –"water consumption per inhabitant". LiWatool differentiates between two values, namely, the 'desired' consumption ("consumo deseado") and the effectively 'distributed' consumption' ("consumo suministrado"). As default setting, LiWatool calculates the 'desired consumption' as long as enough water is available. The 'desired' water consumption per inhabitant per day (average) considers the current water consumption levels of population groups (e. g. belonging to different socio-economical levels NSE, with or without micrometers, and is based on SEDAPAL information) (see Kosow/ Leon/ Schütze 2013:12). Furthermore, in LiWatool not only the *domestic* water consumption is considered, but for instance, water consumption for industry is included, too, and is assumed to be proportional to the domestic consumption (cf. Kosow/Leon/Schütze 2013: 54). To what degree the LiWatool output 'desired' water consumption per inhabitant' and 'CIB descriptor F *domestic* water consumption per capita' are comparable, cannot be fully judged upon at this level of analysis.

Verbal definition of the scenario element *water consumption per capita*l in CIB and in LiWatool

	CIB descriptor	LiWatool output
Label	**"Water consumption per capita (domestic)"** (Source: Descriptor essay, final version and combined scenario brochure, Kosow/ Leon/ Schütze 2013: 50):	**"'desired' water consumption per inhabitant"** (Source: scenario brochure, Kosow/ Leon/ Schütze 2013: 12 and 54, my emphasis)
Definition	"El "consumo de agua" para el descriptor se define como el consumo promedio per cápita y día de la población que cuenta con el servicio de agua potable, ya sea mediante una conexión domiciliaria, una pileta pública o surtidor."(50)	**"**Consumo de agua por habitante por día: Se usan valores diferentes para cada uno de los niveles socioeconómicos (según la experiencia de Sedapal)". (ibid: 54) "Hacemos uso del término "**consumo deseado"** para caracterizar la cantidad de agua que se estma requerida por los usuarios según sus hábitos (consumo diario por habitante según el nivel socioeconómico). Esto no implica que sugiramos que dicho "consumo deseado" representa valores suficientes para la población. Además, es necesario precisar que, si hay menos agua disponible que la considerada como "consumo deseado" (sea por falta de capacidad de plantas de tratamiento de agua potable, sea por caudal insuficiente de los ríos), existerá una diferencia entre la **cantidad "deseada**" y la **cantidad suministrada"** (ibid: 12)

Comparing water consumption/ capita/ day in raw CIB scenarios and as LiWatool simulation output. Source: own representation based on LiWa10cim and Kosow/ Leon/ Schütze 2013, c*hanges between V1 and V2 marked in italic type*.

		A	B1	B2	C	D
	CIB assumption on "Water consumption per capita (domestic)"	F3 Decreasing water consumption per capita	F3 Decreasing water consumption per capita	F3 Decreasing water consumption per capita	F3 Decreasing water consumption per capita	F3 Decreasing water consumption per capita
	CIB impact score	+ 5	+3	+11		+7
V1 integration	LiWatool calculation "**Consumo de agua 'deseado' por habitante (promedio)** (status quo 2011: **174,7** l/capita/day)	137.725 l/capita/day	137.725 l/capita/day	118.557 l/capita/day	121.909 l/capita/day	148.771 l/capita/day
V2 iteration	LiWatool calculation "**Consumo de agua 'deseado' por habitante (promedio)** (*status quo 2011:* ***159.1*** *l/capita/day)*	***143.5 l/capita/day***	***143.5 l/capita/day***	***123.1 l/capita/day***	*(does not correspond to the CIB scenario)*	***127.2 l/capita/day***

Annex RR Scenario <u>structure</u>: Apparent consistency of scenario and sample structure between narrative and numerical parts of the integrated scenarios (Lima Water)

Based on: Supplement C_CIB vs. storylines over time Lima Water, own assessments.
Legend: C = consistent with formulations of the CIB raw scenarios, IC= inconsistent.

	V1 (integration)		**C?**	**V2 (iteration)**		**C?**
	Narrative part „Integration“	**Num. part “TS 3 integration”**		**Narrative part „Itera-tion“**	**Num. part “TS 4 iteration”**	
Reference table (ref-erence sample structure)	***Scenario table March 2013 n=7 CIB reference configurations) second simplifi-cation)***	***Scenario table March 2013 n=7 CIB reference configura-tions***	C	***Final Scenario table Mai 2013 n=6 refer-ence configurations PLUS: Scenario C changed inde-pendently of CIB ma-trix***	***Scenario table Mai 2013 n=6 reference configurations PLUS: Scenario C changed inde-pendently of CIB matrix***	C
Scenario A	CIB config. 10 (dry climate change) Plus CIB config. 3 (wet climage change)	CIB config. 10 (dry climate change) Plus CIB config. 3 (wet climage change) Save factor NOT applied	C	CIB config. 10 (dry climate change) Plus CIB config. 3 (wet climage change)	CIB config. 10 (dry climate change) Plus CIB config. 3 (wet climage change) Save factor NOT applied	C
Scenario B1	CIB config. 9	CIB config. 9 Save factor NOT applied	C	CIB config. 9	CIB config. 9 Save factor NOT applied	C
Scenario B2	CIB config.11	CIB config.11 *Error corrected, reduction of scenario table to <u>one</u> refer-<u>ences config. 11</u>* Save factor NOT applied	C	CIB config.11	CIB config.11 Save factor NOT applied	C
Scenario C	CIB config. 12	CIB config. 12 Save – factor applied	C	New definition of scenario C, no CIB config.	New definition of scenario C, no CIB config. Save – factor ap-plied	C
Scenario D	CIB config. 8 (dry climate change) <u>Plus</u> CIB config, 1 (wet climate change)	CIB config. 8 (dry climate change) Plus CIB config, 1 (wet climate change) Save – factor applied	C	CIB config. 8 (dry climate change) <u>Plus</u> CIB config, 1 (wet climate change)	CIB config. 8 (dry climate change) Plus CIB config, 1 (wet climate change) Save – factor ap-plied	C
Overall scenario and sample structure	Individual scenarios structure and sample structure fully consistent with each other in narrative and numerical parts of all integrated scenarios			Individual scenarios structure and sample structure fully consistent with each other in narrative and numerical parts of all integrated scenarios		

Annex SS Summary: Apparent consistency between integrated scenarios and CIB (Lima Water)

Based on Supplement C_CIB vs. storylines over time Lima Water & supplement D_CIB vs. input data over time Lima Water; own assessments

	Apparent consistency between (Comparison with raw CIB scenarios)			
	Structure		**Content**	
	Indi. scenarios' structure	**Sample structure**	**D&V**	**Interrelations**
Narrative parts (V1 and V2)	Consistent with structure of raw CIB scenario configurations. (except for scenario C in V2).	Consistent with CIB reference scenario sample (except for scenario C in V2).	Overall (rather) *apparently* consistent with raw CIB scenarios, lacking some precision in definitions; adding some new elements but which are not necessarily contradicting; some definitions slightly changed.	Mostly not described in storylines.
Numerical parts (V1 and V2)	Consistent with structure of raw CIB scenario configurations. except for scenario structure of input data representing scenario C in V2 (not based on internally consistent CIB configuration)	Consistent with CIB reference scenario sample (except for scenario C in V2)	**Indicators** (All input data sets): • Out of 13 descriptors somehow quantified in form of input data/parameters. • 5 out of 10 descriptors represented by more than one indicator. • 5 out of 10 indicators only partial representations of descriptors, one indicator 'larger' than descriptor (NSE). • Further specification (and split) of indicators over time. • Overall, translated (parts of) descriptors consistent, except for NSE for poverty **Time-series:** • Overall, TS became more specific and more split over time. • Overall, TS are consistent in direction (all) and spread with variants. • Several TS become more conservative in spread over time, as e. g. C (tariffs), E (poverty) or J (cobertura). • Few TS become larger in spread over time, e. g. M (climate change).	Assumptions on interrelation not visible in time-series – not made explicit in a systematic way – no comparison with CIB possible.
Overall	Consistent. Except for narrative scenario structure of narrative text and of input data representing scenario C in V2 (not based on internally consistent CIB configuration).	Narrative and numerical parts consistent with CIB reference scenario sample (except for scenario C in V2).	Narrative parts quite consistent with raw CIB scenarios, numerical parts are a partial translation, only, translated parts are rather consistent as to choice of (in part partial) indicators (except for poverty) and as to direction of time-series. Spread of time-series became smallest in T2, except for issue M (climate change) (overall, narrative parts more or less consistent).	Integrated scenarios are rather silent on interrelations, comparison with assumptions of CIB only possible for a few narrative descriptions.

Annex TT Scenario <u>content</u>: Comparison of apparent consistency between narrative and numerical parts of the integrated scenarios (Lima Water)

Based on Supplement C_CIB vs. storylines over time Lima Water

Legend: C= consistent; IC= inconsistent; <u>inconsistent elements= underlined</u>*; changes over time= italic type.*

Descriptor	Variants	V1 integration narr vs. num= C? (scenario A, C, D)	V2 iteration narr vs. num= C? (scenario A, C, D)
C Tarifas de agua y saneamiento (conectados)	C1 Reduced (non cost-covering) tariffs	C	C
	C2 Cost-covering tariffs	C	C
D Demografía	D1 High population growth	C	C
	D2 medium population growth	C	C (*<u>albeit same narrative text as in old scenario C is giv-en"ha aumentado</u>"*, the number has been changed into the more medium one).
	D3 Low population growth	C	C
E Pobreza urbana	E1 Increasing poverty	No stand-alone narr. text on poverty, numerical indicator only.	No stand-alone narr. text on poverty, numerical indicator only.
	E3 Constant poverty	No stand-alone narr. text on poverty, numerical indicator only.	No stand-alone narr. text on poverty, numerical indicator only.
	E3 Decreasing poverty	C	C
F Consumo de agua per cápita[444]	F3 Decreasing water consumption per capita ➔SCENARIO A:	No number in text, number in output table only (C)	No number in text, number in output table only (C)
	F3 Decreasing water consumption per capita ➔SCENARIO D:	No number in text, number in output table only (C)	No number in text, number in output table only (C)
G Pérdidas de agua en la red (incl. conex.cland.)	G1 Increasing water network losses	C	C
	G2 Decreasing water network loss-es	C	C
I Forma de desarrollo urbano	I1 City with protection of valleys and green areas	C	C
	I2 City without urban planning and with few green areas	C	C
J Cobertura de agua a la red pública	J1 Decreasing coverage rate	C Text describing reasons for sinking coverage rate only, Giving num. indicator without interpretation.	C Text describing reasons for sinking coverage rate only, Giving num. indicator with-out interpretation.
	J2 constant coverage rate	C	C
	J3 Increasing coverage rate	C	C
K Tratamiento y reuso de	K1 Treatment of 95% with reuse of 5%	C	C

[444] Consumo is sinking across scenarios, but for different reasons, this logic has survived the storyline writing.

Descriptor	Variants	V1 integration narr vs. num= C? (scenario A, C, D)	V2 iteration narr vs. num= C? (scenario A, C, D)
aguas residuales	K2 Treatment of 95% with reuse of 20 to 40%	C	C
L Fuentes de agua disponibles	L1 Increasing water supply	C	C
	L3 Decreasing water supply	C	C
M Cambio climático (caudal de agua y riesgo)	M1 Excessive water flow (flooding)	C	C
	M3 Low water flow (severe droughts)	C	C
Overall apparent consistency between narr. and num. parts		High. For some issue highly integrated such as D Demography with both aspects in one sentence. For some issues, only numerical information without 'qualification' (e. g. E and J), for others only qualitative text , numbers in annex only (F).	Identical assessment as for V1 integration. One exception: New scenario C, narrative text (old) and number (new) might be inconsistent.

Annex UU Summary: Apparent consistency between narrative and numerical parts of integrated scenarios (Lima Water)

Summary of my own assessments.

	Apparent consistency between narrative and numerical parts			
	Structure		Content	
	Indi. scenarios' structure	Sample structure	D&V	Interrelations
V1 "Integration"	C	C	High. For some issue highly integrated as e. g. D Demography with both aspects in one sentence. For some issues, only numerical information without 'qualification' (e. g. E and J), for others only qualitative text, numbers given in annex only (F).	Only a few stated in narrative parts only. No comparison possible.
V2 "Iteration"	C	C	Identical assessment as for V1 integration. One exception: New scenario C, narrative text (old) and number (new) might be inconsistent.	Only a few stated in narrative parts only. No comparison possible.
Overall	Individual scenarios structure and sample structure fully consistent with each other in narrative and numerical parts of all integrated scenarios, both versions of brochures.		Highly consistent.	Only a few explicitly described, and in narrative parts only. No comparison possible.

Erklärung

Ich erkläre, dass ich, abgesehen von den ausdrücklich bezeichneten Hilfsmitteln die Dissertation selbständig verfasst habe. Alle Stellen, die dem Wortlaut oder Sinn nach anderen Werken entnommen sind, wurden durch Angabe der Quellen als Entlehnung kenntlich gemacht.

Karlsruhe, 15.01.2016

Hannah Kosow