Context Scenarios of the German Energy Transition

A data collection for the analysis of the socio-political framework of a socio-technical transformation

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Abstract

An expert survey about the socio-technical context of the German Energy Transformation is described and selected results are reported. Major socio-technical drivers of the energy system and its evolution were identified, alternative futures for each driver were derived based on literature review and expert questioning. Using the framework of Cross-Impact Balance Analysis, the interrelations between the possible futures of the drivers were estimated by a series of expert interviews.

1. Introduction

As a contribution to climate protection and the replacement of nuclear energy, the German federal government plans to extensively restructure the national energy system by 2050. Greenhouse gas emissions are to be reduced by at least 80 % compared with 1990 levels, renewable energies are to cover at least 60 % of gross final energy requirements and primary energy requirements are to fall by at least 50 % (BMWi 2010). This massive transformation of the energy system does not only require the conversion of the technical equipment, it also implies a parallel transformation of energy use behavior, energy industry structures and energy policy governance. It must therefore be seen as a socio-technical transformation.

From this perspective, the scientific preparation and monitoring of the transformation of the energy system requires not only technological research, but also an analysis of the socio-technical

aspects of the transformation process. To strengthen this research perspective, in 2011 a research alliance called "Helmholtz Alliance ENERGY TRANS - Future energy supply infrastructures. At the path to sustainability and social compatibility" was founded[1]. In the ENERGY-TRANS Alliance about 80 social and political scientists, psychologists and philosophers, economists and legal scientists, engineers and system analysts from nine research institutions are doing research and are working together in five research fields, 17 projects and two cross-sectional topics.

Part of the research is to generate orientation knowledge for the transformation process with the help of energy scenarios and to take into account the socio-technical perspective of the alliance in particular. The project "Integrated Scenario Analysis" aims specifically at transformation scenarios of the national socio-technical energy system (other scenario projects of the Alliance are focusing on the European integration of the transformation process or on sectoral or regional specificities). The project is being carried out in cooperation between DLR, ZIRIUS and Forschungszentrum Jülich. To integrate the socio-technical perspective into the model-based scenario construction, the concept of 'context scenarios' (Weimer-Jehle/Prehofer/Vögele 2013, Weimer-Jehle et al. 2016) was used, as in all scenario work of the Alliance. First, a series of "social scenarios" will be developed that describe the embedding of technical transformation in societal change and incorporate the uncertainties of the societal process of change into the analysis.

The societal scenarios are created using the *cross-impact balances* method (CIB[2], Weimer-Jehle 2006), a method for the systematic construction of qualitative scenarios. The CIB analysis is based on data from expert assessments of key factors in the social development directly or indirectly linked to the energy system, its possible future development and interdependencies. In order to collect the relevant data, extensive expert surveys were carried out in 2014 within the project "Integrated Scenario Analysis" . The central steps and selected results of this data collection are documented in this article. Chapter 2 contains an overview of the survey process. Chapter 3 describes the compilation of the 39 scenario factors, the "descriptors". Chapter 4 deals with the processing of the descriptors into "descriptor essays", which contain the definitions of the descriptors and the range of their possible futures. Chapter 5 contains information and aggregated results on the interdependencies between the descriptors. Full documentation of the interdependence data will be provided in a later publication. Chapter 6 describes the construction of consistent scenarios using the CIB algorithm. Chapter 7 finally describes the intended further use of the data material.

2. Overview of the survey steps

The process (which has taken place so far) and the resulting scenario products are briefly described below:

1. The scenario field analysis in the "Integrated Scenario Analysis" project was based on various criteria. On the one hand, the scenarios should be able to exist as stand-alone national social scenarios (with a focus on energy), on the other hand they should be

[1] www.energy-trans.de/english/index.php

[2] http://www.cross-impact.org/

connectable to an energy model. On the basis of these criteria, the social and technical descriptors, which are either important issues in society and/or have a strong influence on important variables of the energy system, were identified in a multi-stage process (the complete list of identified descriptors is presented in Chapter 3).

2. The uncertainty of the development of these descriptors up to 2050 is captured by several specifications for each descriptor. This represents the respective uncertainty space. The content of the 39 descriptors selected for scenario analysis and their expressions were designed by literature research and expert reviews in the form of short essays (see Appendix).

3. In a third step, interviews with experts were conducted to assess the influences between the descriptors, both qualitatively in the form of arguments and semi-quantitatively in the form of 'cross-impacts'. For each descriptor, 1-3 experts were interviewed. Controversial assessments underwent expert review by comparing the different expert assessments for a descriptor: each expert had the opportunity to comment on the arguments and assessments of the other experts or to correct his/their own.

The individual steps are discussed in more detail in the following chapters.

3. Selection of descriptors

On the basis of a literature search (Gallego, Ruddat, Rothmund 2013) and a series of discussions among the experts of the Helmholtz ENERGY-TRANS Alliance, a list of 101 descriptors representing direct or indirect drivers of the development of the energy system was drawn up. The proposal list was sent to all experts of the Helmholtz Alliance and asked for an assessment of the importance of the factors for the description of the transformation process. Based on 27 responses from 16 of the Alliance's 17 projects and taking into account the thematic balance of the disciplines involved, the ZIRIUS project team selected 39 descriptors for the scenario analysis in consultation with the DLR modelers. The list of selected descriptors is given in Table 1.

Table 1: List of selected descriptors

A(I). Global development - General development
A(II). Global development - World market prices for fossil fuels
A(III). Global development - Interest rate development
B. EU integration
C. Population development
D. GDP development
E. Employment market development
F. Tertiarisation of the economy
G. Innovation ability of the economy
H. Transnational trade flows
I. International integration of electricity grids
J. Infrastructure development of electricity grids
K. Expansion of renewable energies (electricity)
L. Tendency centrality/decentrality of power generation/storage
M. Market regulation of the electricity market
N. Policy stability in the field of energy
O. Control instruments in the field of energy
P. Governance in infrastructure development
Q. Planning law / Public infrastructure planning
R. Political guidelines
S. Welfare state development
T. Income distribution
U. Technology acceptance with respect to energy technologies
V. Individual energy consumption behavior
W. Educational development
X. Attitude of the population towards the energy transition / NIMBY
Y. Value orientation / objectives for economic design
Z. Media discourse
a. Development of consumption - Household appliances
b. Efficiency development - passenger cars (electrical)
c. Efficiency development - passenger car (combustion engine)
d. Efficiency development - Buildings (private)
e. Efficiency Development - Industry
f. Efficiency Development - GHD
g. Expansion district heating
h. Investments into new vehicle concepts and into infrastructure
i. Housing trends
j. Expansion of renewables (heat)
k. Rebound in individual energy consumption

The four descriptors A(1) ... B are international descriptors that exert influence on other descriptors but do not themselves receive influence from descriptors outside their group. The 24 descriptors C ... Z are active descriptors that exert influences on other descriptors and are themselves the target of influences. The 11 descriptors a … k are passive descriptors, which receive influences from but do not themselves exert any influence on the active descriptors.

4. Definition of the descriptors and their future variants

For the 39 descriptors, definitions were now worked out together with 2 to 3 experts, partly from the Helmholtz Alliance and partly external experts, if required, and 2 to 4 alternative future developments were defined for each of the 39 descriptors. Table 2 shows the assumed future variants for all descriptors in keywords. The complete descriptor essays are documented in the Appendix.

Table 2: Alternative futures for 39 descriptors. Detailed description in the Appendix.

A(I). Global development - General	A(I)1 Market forces A(I)2 Policy reform A(I)3 Fortress world A(I)4 Eco-communalism
A(II). Global development - World market prices for fossil fuels	A(II)1 Low price path A(II)2 Medium price path A(II)3 High price path
A(III). Global development - Interest rates	A(III)1 Permanent low interest rates A(III)2 Moderate recovery of interest rates A(III)3 Return to historical interest rate levels
B. EU-Integration	B1 EU Renaissance B2 Nobody cares B3 EU under threat
C. Population development	C1 Low population C2 Average population C3 Relatively high population
D. GDP development	D1 Weak development D2 Moderate development D3 Strong development
E. Employment market development	E1 Low unemployment, high flexibilization (employee friendly E2 High unemployment, high flexibilization (employer friendly E3 Labor market split into two parts
F. Tertiarization of the economy	F1 Weak tertiarization F2 Strong tertiarization
G. Innovation ability of the economy	G1 Decreasing innovation ability G2 Stable innovation ability G3 Increasing innovation ability

H. Transnational trade flows	H1 European Germany H2 European Germany – focus on service sector H3 Global Germany H4 Renationalization
I. International integration of electricity grids	I1 Trend towards power autarchy I2 Trend towards a stronger European electricity interconnection together with European power autarchy I3 Trend towards trans-European optimization of supply
J. Infrastructure development of electricity grids	J1 Demand driven expansion J2 Decelerated expansion J3 Strong decelerated expansion
K. Expansions of renewable energies (electricity)	K1 Low expansion K2 Moderate expansion K3 High expansion
L. Tendency centrality/decentrality of power generation/storage	L1 Trend towards integration of decentr. units into the central system L2 Trend towards mixed structure L3 Trend towards conversion to decentralized system architecture
M. Market organization of the electricity market	M1 Arrangement of existing markets (security of supply by market) M2 Transformation of existing markets (security of supply by supplier) M3 Introduction of new markets (security of supply by state)
N. Policy stability in the area of energy	N1 Lower stability N2 Stable stability N3 Higher stability
O. Control elements in the area of energy	O1 Preference for regulatory instruments O2 Preference for technology specific instruments O3 Preference for technology-unspecific economic instruments
P. Governance in infrastructure expansion	P1 Trend towards coordinated expansion P2 Trend towards uncoordinated expansion
Q. Planning law / Public infrastructure planning	Q1 Focus on acceleration Q2 Focus on legitimacy and acceptance Q3 Dominance of particular interests Q4 Compromise
R. Political guidelines	R1 Stronger focus on governmental control R2 Stronger focus on citizen participation and transparency R3 Stronger focus on market mechanisms R4 No shift in weight
S. Welfare state development	S1 Stronger emphasis on liberal welfare elements S2 Stronger emphasis on conservative-corporatist welfare elements S3 Stronger emphasis on social-democratic welfare elements
T. Income distribution	T1 Increasing inequality / income growth weak T2 Inequality constant or declining / income growth weak T3 Increasing inequality / stronger income growth T4 Inequality constant or declining / income growth stronger
U. Acceptance of technologies in the field of energy technologies	U1 Declining U2 Constant U3 Slightly increasing U4 Strongly increasing

V. Individual energy consumption behavior	V1 Trend towards being uninvolved V2 Trends towards economy V3 Trend towards technological affinity V4 Trend towards sustainability
W. Educational development	W1 Strong focus on MINT / low access restrictions W2 Strong focus on MINT / strong access restrictions W3 Strong focus on general education / low access restrictions
X. Attitude of the population towards the transformation of the energy system	X1 Trend towards positive attitude X2 No trend recognizable X3 Trend towards negative attitude
Y. Value orientation / objectives for economic design	Y1 Trend towards materialism and performance Y2 Trend towards sustainable materialism Y3 Trend towards post-materialism Y4 Trend towards differentiation
Z. Media discourse	Z1 High diversity of opinion / strong tabloidization Z2 High diversity of opinion / low tabloidization Z3 Low diversity of opinion / strong tabloidization
a. Consumption development - household appliances	a1 Weak consumption development a2 Strong consumption development
b. Efficiency development - passenger car (electrical)	b1 Weak efficiency development b2 Moderate efficiency development b3 Strong efficiency development
c. Efficiency development - passenger cars (combustion	c1 Weak efficiency development c2 Strong efficiency development
d. Efficiency development - private buildings	d1 Weak efficiency development d2 Moderate efficiency development d3 Strong efficiency development
e. Efficiency development - Industry	e1 Weak efficiency development e2 Strong efficiency development
f. Efficiency development - GHD	f1 Weak efficiency development f2 Moderate efficiency development f3 Strong efficiency development
g. Expansion district heating	g1 No increased expansion of the local and district heating networks g2 Increased expansion of the local and district heating networks g2 Increased expansion of the local and district heating
h. Investments in new vehicle concepts and infrastructure	h1 Low investments h2 Moderate investments h3 High investments
i. Housing trends	i1 Small increase i2 Moderate increase i3 High increase
j. Expansion of renewables (heat)	j1 Low expansion j2 Strong expansion j3 Very strong expansion
k. Rebound in individual energy consumption	k1 Trend towards no rebound k2 Trend towards moderate rebound k3 Trend towards strong rebound

5. Interdependencies

The interdependencies between the descriptors and their alternative futures were assessed in the form of cross-impact assessments in 67 expert interviews. The semi-standardized interviews had a standard duration of 2 hours and each handled a column of the "Cross-Impact Matrix", i.e. all influences on a certain descriptor were discussed. The experts were asked to assess the influence of a particular future of descriptor A on a particular future of descriptor B on an ordinal scale from -3 (strongly inhibiting) to +3 (strongly promoting). An example of a cross-impact assessment is shown in Fig. 1 for how the future of "EU integration" affects the future of "International interdependence of electricity grids".

In addition to the cross-impact assessment, verbal justifications for the judgments were also asked and documented. On average, 2-3 interviews were conducted on the 24 active descriptors. The passive descriptors were covered by only one interview in this phase - due to their passive descriptor status, subsequent surveys are possible at any time without affecting the basic structure of the scenario analysis. The autonomous descriptors did not require interviews. Their only internal dependence concerns the dependence of energy raw material prices (AII) on the global development (AI), which was defined in consultation with the DLR project team.

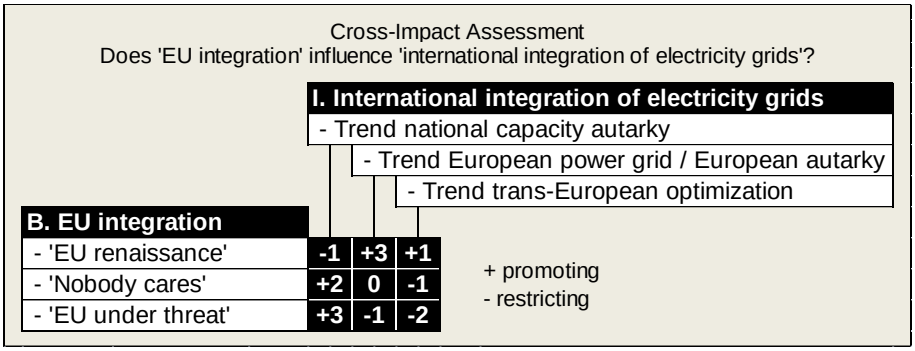

Fig. 1: Example for a cross-impact assessment sector

The interviews resulted in 2,234 cross-impact judgements. The complete cross-impact matrix will be documented in a later publication.

6. Scenarios

Based on the cross-impact data, consistent scenarios can be identified using the CIB algorithm. Scenarios are considered to be consistent if the weighted sum of promoting and inhibiting influences for each descriptor cannot be increased by changing the future assumption for this descriptor (Weimer-Jehle 2006). This condition ensures that each scenario consists of a plausible network of mutually supportive assumptions.

The raw data of the interviews are currently not sufficient for final evaluation, since the cross-impact assessments of the interviewed experts must first be checked for formal methodological validity. Reasons for formal objections against expert evaluations are mainly indirect influence evaluations (A affects B because A affects C and C affects B), which would lead to double evaluations, as well as backward evaluations (which conclude from effects on origins).

7. Outlook

The data collection in the project "Integrated Scenario Analysis" of the Helmholtz-Alliance ENERGY-TRANS creates - after further validation steps - the basis for an algorithmic construction of qualitative scenarios for the socio-economic context of the German energy system transformation. These allow a systematic exploration of the space of possibility for the future development of the embedding society. It is intended to use these context scenarios as a starting point for energy model analyses and to examine them for opportunities and risks for the transformation of the energy system, associated with certain forms of societal development. [3]

The next step in this exploitation process is the selection of different context scenarios for application in energy modelling. However, in order to achieve the highest possible degree of 'robustness' of the scenarios, the experts' assessments of the influences are subjected to further quality checks. This means that it is systematically checked on the basis of the experts' argumentation whether the evaluations were methodologically correct. If, for example, an indirect influence was evaluated contrary to the logic of the method, i.e. a third descriptor from the social model is the actual influent according to the argumentations of the experts, these evaluations are corrected by the ZIRIUS team. Assessments, in which the direction of influence was viewed inversely, contrary to the methodological logic, are also identified and corrected by the quality check. The validated matrix is then converted into a scenario pool, from which the final scenarios which can be combined with the energy modelling can be selected. These are then reviewed for plausibility by the internal and external experts involved and worked out by a storyline in the final step.

Acknowledgement

The data collection was made possible by the cooperation of a total of 71 experts within and outside the Helmholtz Alliance ENERGY-TRANS, for which we would like to express our special thanks. Thanks are also due to Ricarda Scheele, M.Sc. and Dipl.- Ing. Christian León for conducting part of the expert

[3] Translators‘ note: In the meanwhile, a scenario analysis and energy system model analysis based on the described set of descriptors and the cross-impact data was published in: Pregger T., Naegler T., Weimer-Jehle W., Prehofer S., Hauser W. (2019): Moving towards socio-technical scenarios of the German energy transition - lessons learned from integrated energy scenario building. Climatic Change. DOI:10.1007/s10584-019-02598-0.

The German version of the manuscript includes a statistical analysis of the preliminary cross-impact data (Appendix B) and a preliminary list of scenarios resulting from the preliminary cross-impact data (Appendix C). Since final results are available in the meantime (Pregger et al. 2019), this data was omitted in the translated manuscript.

interviews. The work was financed by the Helmholtz Association and the Baden-Württemberg Ministry of Science and Art.

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Appendix: Descriptor-Essays

Energy-Trans

Construction of context scenarios for the transition of the German energy system

Descriptor-Essays

Content

International Factors

A(1) Global development - General development

The work of the Global Scenario Group "Great Transition" is used as a descriptor for global development up to 2050.[45] The following variants are available for development at the global level:

A(I)1. **Market forces:** The logic of growth of the past decades remains unchanged, trade barriers continue to be dismantled and developing and emerging countries are increasingly integrated into the existing global economy. The demand for water, oil and other commodities is growing far less rapidly than the economy; nevertheless, commodity prices and environmental damage are rising, as the growth effect outweighs the efficiency gains. The global population continues to grow rapidly and inequality between developing and developed countries continues to rise. Armed conflicts are becoming more frequent.

A(I)2. **Policy reform:** The expansion of markets and global trade will continue to be pursued in this scenario, too, but at the political level it will take a back seat to the goals of sustainability and poverty reduction. Inter- and transnationally coordinated state agreements and programs are adopted and effectively reduce environmental damage and poverty compared to A(I)1, and income inequalities are also reduced in relation to today. Population and resource needs continue to rise, but less than in this variant. As a result, armed conflicts are decreasing, both in comparison to A(I)1 and in comparison to today.

A(I)3. **Fortress World:** Different from A(I) 2 growing inequalities and the conflicts arising from the increasing need for resources are not countered with international agreements, but with military power, which primarily secures the supply of today's industrial nations. This slows down economic and technological development (except in the military sector) in comparison with the first two variants. From a global perspective, the consumption of resources is increasing and the world population is also growing less than in these variants, while armed conflicts are becoming more frequent. The collapse of the existing order is only prevented by military strength.

A(I)4. **Eco--Communalism:** Compared to the other 3 variants, this development is based on a global paradigm shift towards sustainability. At the political level, global governance structures are strengthening, but they are still open to local and national input. On the one hand, this strongly promotes the worldwide implementation of human rights; on the other hand, sustainability goals can be effectively pursued without levelling out the diversity of the different regions. Compared to the other variants, armed conflicts therefore occur least here, population growth, urbanization, social inequalities and economic performance are lowest here. Consumption patterns, energy supply and economic structures are strongly focused on regional sustainability and self-sufficiency and decentral solutions on a small scale are sought instead of large-scale technologies.

[4] Raskin et al. 2002: Great Transition. The Promise and the Lure of the Times Ahead. Stockholm Environment Institute

[5] However, the extremely positive and extremely negative scenarios are not used.

A(II). Global development - World market prices for fossil fuels

Import prices for the fossil fuels oil, natural gas and hard coal influence society's perceptions, future expectations, behaviour and investment decisions. The development of the oil price (measured in $/b, dollars per barrel) is likely to continue to provide the leading impetus for the development trends of all fossil fuels in the future.

A(II)1. **Low price path:** A stable trend is assumed here. The medium-term average price will remain at the level of recent years until 2050 (for crude oil: around $ 100/b)[6][7]

A(II)2. **Average price path:** A gradual increase in the price level (for oil to approx. 126 $/b) until 2030 and then an accelerated increase (for oil to approx. 166 $/b) until 2050 is assumed.[8]

A(II)3. **High price path:** This assumes an early strong rise in the price level (to around $175/b for oil) by 2030 and then a further rise (to $210/b for oil) by 2050.[9]

In all cases, it can be assumed that the respective trend will be superimposed by strong short-term fluctuations.

[6] In Euro: approx. 560 €/t oil, 7 €/GJ natural gas, 95 €/t SKE hard coal at 2011 prices (based on the mean values for 2009-2012 according to Federal Ministry for Economic Affairs and Energy (BMWi) energy data, April 2014; https://www.bmwi.de/Redaktion/EN/Artikel/Energy/energy-data.html)

[7] The low price variant of the EIA International Energy Outlook 2013 even assumes a decrease to $75/b. By avoiding extreme variants, only a tendency towards stabilisation of the oil price is assumed.

[8] According to: Policy scenarios for climate protection (UBA, 2013), p. 15. In Euro (price basis 2008): around 758 €/t oil, 11.0 €/GJ natural gas, 108 €/SKE hard coal in 2030 and around 999 €/t oil, 13.8 €/GJ natural gas, 131 €/SKE hard coal in 2050.

[9] Value 2030 according to Vögele et al. 2012 "Entwicklungen der Rahmenbedingungen für neue Energietechnologien“, STE Report, Jülich, Germany. Value 2050: WWF 2009 "Modell Deutschland" p. 45 (see EIA International Energy Outlook 2013). Prices in Euro (2007 price basis): 1259 €/t oil, 18.3 €/GJ natural gas, 199 €/t SKE hard coal in 2050.

A(III). Global development - Interest rate development

The real interest rates that investors have to spend on debt service have a massive impact on their investment decisions. They are determined (in addition to individual factors such as the borrower's creditworthiness and the risks of the project) macro-economically by the interest rate level of the capital market. The current real interest rate (e.g. for 10-year US bonds) is around 0 % and is thus historically in a special phase. With a fluctuation interval of (short-term). -5% to (short-term) +7%, the historically most frequent values in the period 1970-2012 are in the range of approx. +4%[10]. It is uncertain whether the current special phase will solidify or whether more normal interest rates will return in the medium term (historically), but this would have a high impact on the costs of investment projects, the willingness of public, commercial and private investors to invest and the relative competitiveness of plants with different cost structures.

A(III)1. **Permanently low interest rates:** The current situation of real interest rates for long-term government bonds with a high credit rating of around 0 % will essentially persist for the coming decades.

A(III)2. **Moderate recovery of interest rates:** In the medium term, real interest rates for long-term government bonds with high credit ratings will recover and stabilize at a moderate level of around 2.5 %.[11]

A(III)3. **Return to historical interest rates:** In the medium term the bond market for high quality government bonds will experience a recovery and return to the historically "normal" level of approx. 4 %.

[10] www.wellenreiter-invest.de

[11] In the OECD Economic Outlook Volume 2012/1, p. 202, real interest rates of 2.9 - 2.4 % for the decade 2020 - 2030 are assumed for the euro zone.

B. EU-Integration

The European context is defined by the three Global Europe 2050 scenarios.[12]

B1. **EU Renaissance:** European integration continues to progress and the EU can thus also promote the implementation of the rule of law and human rights at the global level. It extends further to the east and south and creates political, military and fiscal integration. At EU level, there are climate agreements and smart integration of national supply networks, as well as coordinated expansion of renewables. The high innovative power leads to increasing productivity, so that the EU can easily keep up with other regions economically and politically.

B2. **Nobody Cares:** European integration at a standstill. Due to the lack of a guiding vision, policy reforms at EU level fail to materialise, which also means that common climate and energy goals cannot be achieved. The challenge of demographic change is not being accepted and European society continues to age. The EU thus falls far behind the USA and China in terms of economic growth; full integration of the European market will not be achieved.

B3. **EU under threat:** Fragmented integration of nation states. The EU is facing an economic recession that is provoking protectionist reactions. This is slowing down infrastructure development considerably. National governments become more radical and important states withdraw from the EU. Climate and energy policies are not pursued at the European level, which means that food and oil price shocks become entrenched and the European network infrastructure becomes flawed and prone to disruption. Productivity in the EU area will thus be hampered even more than in "Nobody cares", and Europe is falling even further behind the other world regions in economic terms.

[12] European Commission 2011: Global Europe 2050

National Factors / General Development

C. Population development

The development of the German resident population up to 2050 (2008: 82.0 million) will be characterized above all by three uncertainties for the future: the further development of the birth rate, life expectancy and the migration balance. These uncertainties will determine the population figures and also the age structure. According to the population projections of the Federal Statistical Office[13], the following probable ranges are expected by 2050:

Birth rate (children/women, today 1.4):	between 1.24 and 1.56 in 2050
Increase in life expectancy (average man/woman):	between 5.8 and 7.8 years in 2050
Long-term migration balance:	between +100,000 and +200,000 persons/year

Of the variants of the Federal Statistical Office, the two variants that lead to extreme developments in population numbers and a medium variant are used here.

- **C1.** **Low population:** Population will fall to 67.4 million by 2050 with moderate to severe ageing.[14]
- **C2.** **Medium population:** Population will fall to 72.4 million by 2050 with medium ageing.[15]
- **C3.** **Relatively high population:** Population declines to 78.7 million by 2050 with moderate to low ageing.[16][17]

[13] Federal Statistical Office (2009): Population of Germany up to 2060 -- 12. Coordinated population projection, https://www.destatis.de/EN/Home/_node.html. For reasons of consistency, the lower values in the population statistics that have become known in the meantime are not taken into account here.
[14] Federal Statistical Office variant 5W1
[15] Federal Statistical Office variant 3W1. The result of this variant is approx. the same as the UN forecast for Germany 2050 with 72.566 million (World population 2012, UN population division, www.unpopulation.org)
[16] Federal Statistical Office variant 4W2
[17] Due to the current high migration balance, Federal Statistical Office makes new projections, which cannot be taken into account.

National Factors / “Economy“ Sector

D. GDP development

As a measure of the economic performance of an economy, gross domestic product represents the total value of all goods and services produced within a year and used for final consumption.

D1. **Weak development:** For the weak development an annual growth of 0.6 %/year is assumed due to unfavourable influences or deliberate change to qualitative growth.

D2. **Moderate development:** Average annual growth of approx. 1.2 %/year is assumed for the average development.

D3. **Strong development:** The strong development, a very optimistic variant, with an average of approx. 1.8 %/year is just above the assumed growth of the most positive assessment[18] of the known long-term scenarios for Germany.

[18] FfE Forschungsstelle für Energiewirtschaft 2009: „Energiezukunft 2050“. https://www.ffe.de/taetigkeitsfelder/energiebedarfsprognosen-struktur-und-marktanalysen/257-energiezukunft-2050.

E. Emplyoment market development

Since the 1990s there has been a strong change in the forms of employment in Germany: the importance of standard forms of employment has declined significantly and atypical forms of employment have increased significantly. This is due not only to political reforms, but also to structural changes such as the constant development of the labor force potential.[19]

The discussion about the future development of the labor market has for some time been oscillating between the two poles of high unemployment, combined with the decoupling of large population groups from working life and full employment, combined with a shortage of skilled workers.[20] In order to outline conceivable developments also over a longer period of time, the two axes of labor market flexibilization - i.e. the increase in atypical forms of employment - and employment rate are focused in particular. This leads to the following variants of the development:

E1. **Low unemployment, high flexibilization (worker-friendly):** The labor force is not sufficient across sectors to meet the demand on the labor market; employers are therefore forced to increase the potential of the labor force as much as possible through worker-friendly and flexible forms of employment.

E2. **High unemployment, high flexibility (employer-friendly):** The supply of workers clearly exceeds the demand in most sectors and employers can therefore enforce flexible forms of employment tailored to them in their favor.

E3. **Labor market split:** Low flexibility and low unemployment for the highly skilled, high unemployment, high employer-oriented flexibility for the low-skilled.

[19] Himsel, et al. 2013: Erwerbslandschaft im Umbruch: Was die Reformen zum Wandel der Beschäftigungsformen beigetragen haben. In: IAB-Forum, No 2, p. 28 - 35.

[20] Dietz, et al. 2010: Der Arbeitsmarkt der Zukunft * Trends und Perspektiven. In: Vorgänge. Zeitschrift für Bürgerrechte und Gesellschaftspolitik, Vol. 49, Issue 3, p. 4 - 17. (ISSN 0507-4150, Publisher humanistische-union) http://www.humanistische-union.de/nc/publikationen/vorgaenge/online_artikel/230/.

F. Tertiarization of the economy

The share of the tertiary sector in GDP is seen in many places as an indicator of the modernization of an industrial society towards a knowledge and service society. The size of the service sector influences the type of jobs offered and the skills needs of the economy. Moreover, a shrinking secondary sector would change the demand for energy. Currently, the share of employees in the tertiary sector subject to social insurance is about 69% of all employees.[21]

F1. **Weak tertiarization:** This means stagnation or only a slight increase in the current share of employees in this sector (approx. 70%).

F2. **Strong tertiarization:** In this variant, the trend towards the knowledge and service society observed in recent decades continues in the long term and the proportion of people employed in this sector is expected to increase to approx. 80 % by 2050.[22]

[21] Statistik der Bundesagentur für Arbeit; Zahlen, Daten, Fakten: Strukturdaten und -indikatoren; Regional-direktionen und Bundesländer, Hannover, Germany, Dezember 2013;

[22] WWF 2009: „Modell Deutschland. Klimaschutz bis 2050: Vom Ziel her denken". https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Modell_Deutschland_Teil1.pdf

G. Innovation ability of the economy

The ability of the German economy to innovate is understood here as its ability to continuously produce innovations in many sectors, although the situation in the various sectors can vary greatly. Overall, Germany currently occupies a good, but not an outstanding, place among the economic nations.[23] For the future development up to 2050, the following variants are taken into account:

G1. **Decreasing innovative ability:** In Germany, important prerequisites for innovative ability are deteriorating. Due to structural preservation tendencies, weaknesses in innovation are also evident in forward-looking sectors. As a result, the country's innovative ability will gradually decline to a mediocre level among the major economic nations by 2050.

G2. **Stable innovative ability:** Germany will continue to occupy a good but not an outstanding position in terms of the innovative ability of its national economy until 2050.

G3. **Increasing innovative ability:** In Germany, important prerequisites for the ability to innovate are improving. Sectors in which Germany's innovative ability is strong are also proving to be of increasing economic importance. As a result, the country continuously improves the innovative ability of its economy and takes a leading position in 2050.

[23] In an "innovation indicator" calculated by FhG ISI, ZEW, BDI and UNU-MERIT and covering aspects of business, science, education, government and society in a field of 28 economic nations Germany occupies a position fluctuating between 10th and 4th place between 1995 and 2012 (Deutsche Telekom Stiftung, Bundesverband der Deutschen Industrie e.V. (BDI), FhG ISI, ZEW, UNU-MERIT: “Innovationsindikator 2013”. http://www.innovationsindikator.de/fileadmin/content/2018/pdf/ausgaben/innovationsindikator_2013.pdf

H. Transnational trade flows

Will Germany tie up stronger global ties in foreign trade until 2050 or is the main focus of trade within the EU? The OECD/WTO indicator "Trade in Value Added (TiVA)" can be used as an indicator for this question. It measures the share of a country's GDP generated by foreign demand for goods and services. For the German economy, this ratio shows a long-term upward trend and reached around 25 % in 2009 (1995: around 17 %)[24][25]. The share of intra-EU trade (i.e. trade with EU partners) accounted for around half of this volume in 2009 with about 12 %. In addition to the expansion of trade with the USA, the high dynamics of trade with China also contributed to the growth of transnational trade flows outside the EU27.[26] What will happen next?

H1. **European Germany:** The economic importance of international trade relations for Germany continues to grow, above all due to the expansion of Germany´s internal EU trade.

H2. **European Germany - Focus on services:** The economic importance of international trade relations for Germany continues to grow, above all due to the expansion of internal EU trade. Germany is also developing into a significant exporter of financial and other services.

H3. **Global Germany:** The economic importance of international trade relations continues to grow for Germany, above all due to the expansion of global trade beyond EU. The value chains are being further subdivided. The relative importance of intra-EU trade is declining.

H4. **Renationalization:** International trade relations in Germany will experience a gradual change in trend over the coming decades and will decline again, with a simultaneous tendency towards re-integration of value chains in the country.

[24] OECD.StatExtracts, https://stats.oecd.org/, retrieved on 13.06.2014

[25] Germany thus occupies a leading position among the major European countries. According to OECD statistics, the EU average was around 11 % in 2009.

[26] OECD.StatExtracts, https://stats.oecd.org/, retrieved on 13.06.2014

I. International integration of electricity grids

With regard to the integration of renewables into the electricity mix, stronger international integration of the electricity grids has the potential to balance demand and production fluctuations across national borders. It also facilitates international electricity trading.

For the future development of the international integration of electricity grids, three models for expansion are currently under discussion:

I1. **Trend towards national power self-sufficiency:** The optimization of the electricity supply remains limited to the national framework, the international integration of the electricity grids will not be further promoted, since the German security of supply is to be secured by national power self-sufficiency.[27]

I2. **Trend towards a stronger European electricity network with European self-sufficiency:** The international integration of electricity grids remains limited to European countries. The focus is on European self-sufficiency. The network will be used across borders for pan-European optimization.

I3. **Trend towards trans-European optimization of supply:** The international integration of the electricity grids will be extended to the Middle East and North Africa in order to enable particularly solar electricity imports from these regions to Europe.[28]

[27] Feix, et al. 2014: „Netzentwicklungsplan 2014: Erster Entwurf der Übertragungsnetzbetreiber". http://doczz.net/doc/2438608/nep-2014-teil-1---netzentwicklungsplan

[28] DLR 2006: Trans-Mediterranean Interconnection for Concentrating Solar Power. Stuttgart, Germany, 2006 https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/projects/TRANS-CSP_Full_Report_Final.pdf

J. Infrastructure development of electricity grids

The expansion of renewable energies (RE) is closely linked to the expansion or conversion of electricity grids. Depending on the degree of decentralization of renewable energy expansion, the distribution grids will have to be expanded to a greater or lesser extent in addition to the transmission grids.

At present, the rate of expansion is not achieving the targets set; in the first quarter of 2014, only 30 km of new transmission lines were put into operation.[29] As expansion planning is constantly being updated and no long-term plans exist until 2050, the following development variants are not given in line kilometers or percentages of completion. Instead, the variants are based on whether and to what extent the grid expansion is lagging behind the demand resulting from the RE expansion.

J1. **Grid Expansion in line with demand:** The grid expansion keeps pace with the expansion of renewables so that the electricity grid is not a bottleneck in terms of integrating renewables.

J2. **Slower grid expansion:** The expansion of the grid is hampering the integration of renewables and is lagging behind the expansion targets by around 5 years.

J3. **Strong slowdown in grid expansion:** The expansion of the grid is having a strong impact on the integration of renewables and is lagging behind the expansion targets by around 10 years.

[29] Bundesnetzagentur (2014): EnLAG-Monitoring. Stand zum Ausbau von Energieleitungen nach dem Energieleitungsausbaugesetz (EnLAG) zum ersten Quartal 2014.

K. Expansion of renewable energies (electricity)

The amount of investment into the expansion of renewables for electricity generation determines the share of renewables (for electricity generation) in the energy mix in 2050 and the amount of electricity that can be produced from renewables in Germany. The amount of renewable electricity that can be produced also depends on the effect of technological learning and economies of scale. In 2012, 142 TWh of electricity were generated from renewables.[30] This corresponds to an average increase of around 10 TWh/year in the decade 2002-2012.

K1. **Low expansion:** If only small investments are made to expand renewables to generate electricity, around 300 TWh can be generated from renewables in 2050.[31] This corresponds to an average increase of around 4 TWh/year.

K2. **Moderate expansion:** If moderate investments are made, around 450 TWh/year can be generated from renewable sources by 2050.[32] This corresponds to an average increase of around 8 TWh/year.

K3. **High expansion:** If the trend is towards high investments, approx. 700 TWh[33] can be generated from renewable sources by 2050. This corresponds to an average increase of around 15 TWh/year.

[30] Federal Ministry for Economic Affairs and Energy (BMWi) energy data, April 2014; https://www.bmwi.de/Redaktion/EN/Artikel/Energy/energy-data.html)

[31] According to Fahl et al. 2009, p. 191

[32] According to Exxon 2012, 4 (2040: 46 t SKE); Nitsch et al. 2012: Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/leitstudie2011_bf.pdf, p. 114 (427 TWh/year)

[33] According to Sachverständigenrat für Umweltfragen (SRU) 2011. Wege zur 100% erneuerbaren Stromversorgung, ISBN 978-3-503-13606-3, Erich-Schmidt-Verlag, Berlin, Germany, p. 152, https://www.umweltrat.de/SharedDocs/Downloads/DE/02_Sondergutachten/2008_2012/2011_07_SG_Wege_zur_100_Prozent_erneuerbaren_Stromversorgung.pdf?__blob=publicationFile&v=12

L. Tendency centrality / decentrality of power generation / storage

Can a decentralized system architecture for electricity generation and storage become established in Germany and develop a completely new energy system with a completely new constellation of actors, or is an attempt being made to maintain a central infrastructure in principle and to integrate existing and future decentralized plants into it? A characteristic feature of a central architecture in the field of electricity is the dominance of large, remote power plants (such as fossil/nuclear or solar large-scale power plants, large wind parks, large pumped storage power plants, ...), which are centrally controlled and feed in at the high or extra-high voltage level. Characteristics of a decentralized architecture are the dominance of small and medium-sized power plants near to consumption (CHP, small PV/solar plants, small wind farms, home battery storage, ...), which are controlled decentrally (SmartGrids) and feed into the low or medium-voltage grids.

L1. **Trend towards integration of decentralized units into the central system:** In 2050, electricity production in Germany will continue to be controlled centrally for the most part, generated in large units far from consumption, stored if necessary and fed into the high-voltage or extra-high voltage grid or fed directly into the consumption hot spots via individual HVDC lines.

L2. **Trend towards a mixed structure:** Concepts for the equal coexistence of centralized and decentralized generation and storage potentials are developed and implemented.

L3. **Trend towards conversion into a decentralized system architecture:** Electricity production in Germany is increasingly and by 2050 predominantly decentralized controlled, generated close to consumption in small and medium-size units, stored if necessary, consumed as own consumption or fed into the low and medium voltage grid.

In this descriptor, the technical structures are addressed (not the question of concentration vs. distribution of generation plant ownership).

M. Market regulation of electricity market

The suitability of the "energy-only" market introduced after the electricity market liberalization in order to permanently guarantee security of supply under energy transition conditions is subject of controversial debate in Germany. Given current overcapacities and a resulting drop in stock market prices, sufficient investment incentives for the construction of new flexible capacities could be lacking and a deficit in secured capacity could arise in the long term. To bridge the gap until the planned reorganization of the electricity market, a temporary solution limited until 2017 was introduced in 2012 including an auctioned grid reserve. For the future, designs such as capacity markets, establishing a strategic reserve or privatization of supply security through power certificates are being discussed.[34] The directions in which a reorganization of the German electricity market could take place are described by three exemplary variants:

M1. **Design of existing markets (security of supply through market):** To ensure long-term security of supply, adjustment measures are implemented in existing markets, e.g. by introducing longer-term products on the control energy markets or by abolishing price caps on the energy-only market.

M2. **Transformation of existing markets (security of supply by provider):** By removing renewable energies from the energy-only market, the market could be transformed into a residual load market, for example.

M3. **Introduction of new markets (security of supply by the state):** The energy-only market is supplemented by the introduction of a regulated incentive system, such as a central capacity market or a strategic reserve.

[34] Agora Energiewende (2013): Kapazitätsmarkt oder strategische Reserve - Was ist der nächste Schritt?, Berlin. https://static.agora-energiewende.de/fileadmin2/Projekte/2012/Kapazitaetsmarkt-oder-strategische-Reserve/Agora_Hintergrund_Kapazitaetsmarkt_oder_strategische_Reserve_web.pdf

National Factors / Sector "Policy"

N. Policy stability in the field of energy

In German energy policy[35], there are both, areas that are characterized by a high degree of stability in the paradigms that characterize them, and elements that have been subject to strong fluctuations regarding political priorities and legal framework conditions. Between 2000 and 2014, for example, the details and pay rates of the Renewable Energy Act (EEG) were repeatedly adjusted and changed, but the underlying idea of a guaranteed feed-in rate and a secure minimum pay rate was not changed in these 15 years. Nor were the 20-year guaranteed pay rates for built plants changed retrospectively during this period.

In contrast, between 2000 and 2011 the legal framework conditions with regard to the operating time of nuclear power plants were changed relatively frequently and commitments made to existing plants were revised subsequently. After the Federal Government had decided to phase out nuclear power in 2000 by means of an agreement with the energy supply companies, the operating time conditions in this agreement were extended again in 2010. In 2011, this extension was withdrawn after the Fukushima accident.

On a very abstract level, the descriptor Policy Stability is intended to describe how stable the political framework conditions in the energy sector are in the long term with regard to the paradigm and the legal framework conditions. Are there, on average, more areas of high stability than in the past 15 years, or are there more areas than in the past 15 years with framework changes and revisions of commitments?

N1. **Less policy stability:** The policy framework and paradigms pursued are proving to be more unstable compared with the past decade. Policy adjustments are more frequent. Once decisions have been made, they are revised more frequently and many reforms take place; new demands can be met more quickly, but fewer reform projects are implemented to the end because they are revised rather frequently.

N2. **Constant policy stability:** The stability of the policy framework and the paradigms pursued does not change compared with the past 15 years.

N3. **Higher policy stability:** The policy framework and paradigms pursued are proving to be more stable compared to the past decade. Policy adjustments tend to take place more slowly. Once decisions have been made, they are revised less frequently and fewer reforms are carried out; as a result, the response to new challenges is relatively slow.

[35] In this context, energy policy is defined as "the totality of sovereign regulations and measures affecting the behavior of suppliers and consumers of energy products (coal, oil, gas, electricity, etc.)". Hohensee/Salewski (Ed.) 1993: Energie-Politik-Geschichte: nationale und internationale Energiepolitik seit 1945. Steiner-Verlag, Stuttgart, p. 7

O. Control instruments in the field of energy

In principle, energy policy instruments can be designed as regulatory or economic instruments. In practice, hybrid forms are also frequently used.

Regulatory instruments use commandments and prohibitions for the action of defined actors to achieve socially defined goals (e.g. efficiency standards for household appliances or admixture obligations for fuels). Economic instruments, on the other hand, use monetary incentives to influence actions of policy addressees, presumably acting economically rational, in a socially desirable direction, without specifically prescribing this (e.g. emission trading, electricity tax). Hybrid forms combine both approaches (e.g. energy savings obligations including the possibility of certificate trading).

With both types, certain impact risks can occur (although also depending on the concrete implementation). It is discussed in the literature that regulatory instruments may be at risk of low cost efficiency due to asymmetric distribution of information between regulators and policy addressees (e.g. due to high control costs or the exclusion of cheaper alternatives). In the case of economic instruments, it is discussed that implicit assumptions regarding the economic rationality of the actors and the perfect equal distribution of information among the policy addressees cause a fundamental weakness of this type of instrument, resulting in the risk of missed targets and cost inefficiency.

In general, a mixed instrumentation is to be expected for German energy policy in the areas of electricity, heat and transport in the future, whereby different priorities are conceivable:

- **O1.** **Preference for regulatory instruments:** Unless there are predominant reasons for a different choice, the legislator prefers regulatory instruments.
- **O2.** **Preference for technology-specific economic instruments:** Unless there are predominant reasons for a different choice, the legislator prefers economic instruments that relate specifically to particular technologies (example renewable energy act, EEG)
- **O3.** **Preference for technology-unspecific economic instruments:** Unless there are predominant reasons for a different choice, the legislator prefers economic instruments that do not relate to specific technologies (e.g. emission trading).

P. Governance of infrastructure development

Governance here is understood as institutionalized modes of social coordination of action through which binding regulations (policies) are adopted and implemented.[36]

The federal government, the states, local authorities, companies, the agricultural sector, associations and not least the public are all involved in the expansion of the infrastructure necessary for the transformation of the energy system (here: plants, distribution and transmission grids), but diverging priorities are often pursued. This results in conflicts over land use and distribution, acceptance problems[37], and target inconsistencies (e.g. between federal and state objectives). In order to achieve the basic framework conditions and process conditions required for a coordinated reconstruction and expansion of infrastructures, governance at the federal level is important.[38]

P1. **Trend towards coordinated expansion:** Basic framework conditions and process conditions can be defined, thereby creating the conditions for coordinated reconstruction and expansion of infrastructures.

P2. **Trend towards uncoordinated expansion:** The federal government's coordination efforts are not effective enough to establish basic framework conditions and process conditions. This leads to an uncoordinated reconstruction and expansion of infrastructures.

[36] Mayntz, R. 2004: Governance im modernen Staat. In: Benz, A. (ed.): Regieren in komplexen Regelsystemen. Eine Einführung, VS Verlag für Sozialwissenschaften, Wiesbaden, Germany, pp. 65 - 75.
[37] Klagge 2013
[38] Ohlhorst et al. 2013; Klagge 2013

Q. Planning Law / Public infrastructure planning

Participation measures in and prior to planning procedures should have an integrating effect and thus increase the transparency, legitimacy and acceptance of planning. These measures should avoid conflicts, legal actions and delays of procedures and contribute to a content-related optimization of planning.[39] For example, the amended Energy Economy Act and the Gid Expansion Acceleration Act provide for (at least) one form of public participation at every planning stage.[40] However, in the future, a certain trade-off could arise in the further development of planning law between the objective of making planning more legitimate, more inclusive, more transparent and thus more acceptable through participation, and the objective of accelerating planning processes. This raises the question of what priorities the German legislator will set in the future in developing legislation for the field of public infrastructure planning, including energy infrastructure planning. It cannot be excluded that participation measures may be carried out by local actors without an obligation under planning law.

Q1. **Focus on acceleration:** Planning law will be further developed above all with the aim of streamlining and accelerating planning procedures. Participation measures are mainly provided for insofar as they appear to be necessary to avoid legal actions and delays in proceedings, and thus serve this objective.

Q2. **Focus on legitimization and acceptance:** Planning law will be further developed above all with the aim of legitimizing planning procedures through inclusion and transparency, increasing their acceptability and also improving the planning result through suggestions of involved actors. Accordingly, intensive participation measures are planned, even if this has a negative impact on further acceleration of procedures.

Q3. **Dominance of particular interests:** Planning law is not developed further according to criteria of inclusion and transparency, and the predominance of economic interests in the negotiation processes within the framework of public infrastructure planning is becoming increasingly frequent. Where participation measures are envisaged, they are carried out more formally and less in the spirit of serious participation.

Q4. **Compromise:** The aim of the further development of planning law in this variant is to pursue the objectives of Q1 and Q2 at the same time, whereby none of the specific advantages of these two variants can be fully achieved, but their disadvantages are also mitigated.

[39] Krautzberger, M.: Wie steht es mit der Bürgerbeteiligung im Planungsrecht? Flächenmanagement und Bodenordnung 2/2013. http://www.krautzberger.info/files/2012/03/0_fub_2_13_Krautzberger1.pdf

[40] Schadle, K.: Neue Leitungen braucht das Land -- und Europa! Zeitschrift für neues Energierecht, 2/2013

R. Political guidelines

As the central legal document of a state, the constitution - in Germany the Basic Constitutional Law - also provides a definition of the state's objectives. From a structural-functionalist point of view, it thus guarantees in modern states, in particular, the governance of the state, democratization, the enforcement of civil and equality rights and the limitation of state power.[41] In Germany, governance performance is traditionally given higher priority than in more liberal states such as the USA or Great Britain, where the limitation of state power is more important.[42]

In order to outline the future development of the state governance goals in Germany up to 2050, the possible variants should be oriented towards a growing dominance of one of these functions compared to today. These functions can become manifest in either a change of interpretation practice or concrete changes in legislation.

R1. **Greater focus on state control:** Societal problems are increasingly being addressed by a law-and-order policy. Regulations and laws are becoming more detailed, increasing in quantity and being monitored more and more strictly. For this, the judiciary and the executive authority are being strongly expanded.

R2. **Greater focus on citizen participation and transparency:** Referendums and direct-democratic elements are being expanded. Transparency will be increased in the filling of key positions, official functions and calls for bids.

R3. **Greater focus on market mechanisms:** New challenges are more strongly regulated by market mechanisms, which the state monitors only very generally. Thus, economic actors have greater room for maneuver than in R1. Major projects are rarely carried out by the state. Approval procedures are simplified and influenced less by prior consultations than by legal acts of affected citizens.

R4. **No focus shift:** In future development, none of the areas mentioned will be emphasized more strongly than at present.

[41] Münch 1984: Die Struktur der Moderne.
[42] Münch 1986: Die Kultur der Moderne.

S. Welfare state development

The outline of the welfare state development shall be based on the widespread typology of Esping-Andersen, which characterizes three types of welfare states:

Liberal welfare state: The coverage of typical risks (old age, illness, unemployment, etc.) follows the principle of privately organized self-help; private insurance, tax relief for high-performer and a pronounced culture of donation and patronage characterize this type. Poverty policy concentrates on people who have fallen into need through "no fault" of their own. Its services are strictly needs-tested, often short-term and at best securing an existential minimum. Self-help through paid work is strongly expected of people who are able to work, thus it has priority over any social benefit. A citizen's right to a social benefit does not exist.

Conservative-corporatist welfare state: This type protects typical risks of wage workers and their family mainly through various social insurances, which are administered and controlled corporately by employers' and employees' associations. Therefore, self-help in the form of company pension plans or private provision plays a rather minor role in pension and health insurance, for example. Contributions to social insurance are wage-related, as are cash benefits in the case of compensation (old age, unemployment). Social insurance, therefore, reproduces social status and group differences. The non-contributory co-insurance of family members who are not gainfully employed or not capable of working helps to preserve the classical breadwinner model.

Social-democratic welfare state: Ideally, this type guarantees citizens indiscriminately equal basic security benefits for all admitted risk situations, i.e. "equality of the highest standards instead of equality of minimum needs". Both, women and men are equally conceived as working citizens and parents; the welfare state helps them to realize this equality as far as possible. It invests early in children as future citizens.[43]

In the past two decades, the German welfare state has in some areas developed away from the conservative corporatist model, for which Germany was the model until the 1990s. It has implemented both liberal measures (e.g. by strengthening the principle of "demanding and promoting", especially in the basic security for job seekers) and social democratic measures (e.g. parental allowance, expansion of public all-day care and all-day schools).

The variants of the future development are to be described in an approximation to one of these ideal types and consist of:

S1. Stronger emphasis on liberal welfare elements
S2. Stronger emphasis on conservative-corporatist welfare elements
S3. Stronger emphasis on social-democratic welfare elements

[43] Esping-Andersen 1990: The Three Worlds of Welfare Capitalism. Polity Press. Cambridge.

National Factors / ”Society" Sector

T. Income distribution

As two of several indicators to measure prosperity[44], "unequal distribution of disposable income" and "average disposable income" are to be considered in more detail here, as these are most frequently used to measure prosperity.

Since the mid-1980s, there has been a trend in Germany towards a more unequal distribution of disposable income.[45] As a result, the unequal distribution of disposable income in Germany at the beginning of the 2010s is much more pronounced than at the beginning of the 1980s. At the same time, average disposable income (measured by median income) as an indicator of the average development of prosperity, showed clear signs of stagnation, especially during the 2000s, and at the beginning of the 2010s it was at roughly the same level as at the beginning of the 2000s. How will the two prosperity indicators "Inequality of disposable income" and "Mean disposable income" develop up to 2050?

T1. **Further increasing inequality with further weak or stagnating growth of average income:** The long-term trend towards more income inequality will continue until 2050 with simultaneously weak or stagnating growth of average income.

T2. **Constant or even declining inequality with further weak or stagnating growth of average income:** The trend towards greater income inequality will not continue in the medium term or even be reversed, but the general growth of average income will still stagnate.

T3. **Further rising inequality with simultaneous growth of average income:** The long-term trend towards greater income inequality continues until 2050, but is accompanied by significant growth in average income.

T4. **Constant or even declining inequality with simultaneous growth of average income:** The trend towards greater income inequality does not continue or is even reversed and is additionally accompanied by a clear growth of average income.

[44] Enquete Kommission des Bundestages 2013: Wachstum, Wohlstand, Lebensqualität - Wege zu nachhaltigem Wirtschaften und gesellschaftlichem Fortschritt in der Sozialen Marktwirtschaft. Final report. p. 28, (additional indicators GDP, public debt, freedom, health, education, employment, greenhouse gas emissions national, nitrogen national, biodiversity national)

[45] For the following explanations, see Grabka/Göbel (DIW Wochenbericht, No 46, 2013) and OECD („Growing Unequal? Income Distribution and Poverty in OECD Countries", Paris, 2008; "Divided We Stand: Why Inequality Keeps Rising", Paris, 2011) and IAW as well as University of Tübingen („Aktualisierung der Berichterstattung über die Verteilung von Einkommen und Vermögen in Deutschland", Endbericht, BMAS, 2011).

U. Acceptance of energy technologies

In people's perception, techniques are often associated with risks. These perceived risks affect the acceptance and thus also the implementation of technologies, especially if they are not self-operated (e.g. fracking, CCS, wind turbines). The risk perception of a society can vary substantially. Germany is not an anti-technology country, but views technology, compared to the EU27 average, more soberly, more differentiated and partly more skeptically. In particular when it comes to scientifically controversially discussed technologies such as nuclear power plants, fracking or CCS, the skepticism in Germany is much stronger.[46]

U1. **Declining:** The Germans' acceptance of technologies (that they do not operate themselves) will fall by 2050 and they will no longer differentiate so strongly between technologies. The motto is "wait and see". Only when energy technologies with perceived risks, regardless of their opportunities for individuals or society as a whole, have proven their worth in other countries for a longer period of time, implementation will be accepted in Germany.

U2. **Constant:** There will be little change in the acceptance of technologies by the German population, who will have a balanced position and differentiate between technologies. Slightly proven and tested technologies with anticipated strong risks, such as CCS or fracking, are more opposed than less controversial technologies. The latter are accepted provided that a fair distribution of opportunities and risks in society is guaranteed and there is trust in the actors.

U3. **Slightly increasing:** There will be little change in the acceptance of technologies by the German population, who will have a balanced position and differentiate between technologies. People are more opposed to less proven and tested technologies with anticipated strong risks, such as CCS or fracking, than they are to less controversially discussed ones. Energy technologies with low perceived risks, such as wind turbines, are, however, viewed positively by Germans.

U4. **Strongly increasing:** The technology acceptance of Germans for technologies not operated by themselves will increase until 2050. This means that even if opportunities and risks are unequally distributed in society, technologies perceived as risky will be accepted if they are considered useful for the society as a whole.

[46] Weyer et al. 2012, Zusammenfassung: „Technikakzeptanz in Deutschland und Europa“, https://www.cssa-wiesbaden.de/fileadmin/Dokumente/Wirtschaftsethik/Materialien/Industrie_2020/Technikakzeptanz_Studie/Zusammenfassung_Studie_Technikakzeptanz_2012.pdf, p. 2

V. Individual energy consumption behavior

How will the majority of people in Germany behave until 2050 when it comes to personal energy consumption? The literature generally distinguishes between "Efficiency investment behavior" and "Curtailment behavior".[47] The former are so-called one-time actions, i.e. investments in efficient products. Instead, curtailment behavior is concerned with changing habits in everyday life, i.e. more efficient or even the partial resign of energy consumption. The Germans are currently showing a tendency towards "efficiency investment behavior", but almost no "curtailment behavior". Which kind of behavior will dominate in the future?

V1: **Trend towards being uninvolved:** Little will be invested in more energy-efficient products, nor are attempts being made to save energy by changing behavior.

V2. **Trend towards thriftiness:** No or only little energy-efficient products will be bought - above all, attempts are made to save energy by changing habits.

V3. **Trend towards technology affinity:** A great deal is invested in energy-efficient technologies. Changes in consumer habits are not being sought here.

V4. **Trend towards sustainability:** A great deal is invested in energy-efficient appliances and products in the same category are preferred. At the same time, efforts are also being made to reduce energy consumption by adopting more economical behavior.

[47] http://mechanisms.energychange.info/backgrounds/2, retrieved on 27.11.2020

W. Educational development

The understanding of education in Germany has changed several times over time. Two developments have been of particular importance since the 1960s: Whereas the expansion of education in the 1960s and 1970s focused primarily on democratizing access, the educational discourse from the 1980s onwards was conducted primarily with a view to the resulting suitability for the labor market. Education is increasingly assumed as a location factor or human capital.[48] Since then, there has also been a steadily growing focus on natural sciences and applied research, as well as a strong focus on promoting competition and elites[49], although access to the education system in Germany is still substantially dependent on the social status of parents.[50]

The variants of future development opportunities are therefore oriented towards these two dimensions.

W1. **Strong application focus on MINT[51]/low access restrictions:** Schools and universities are transforming themselves even more into pure training centers for industry, and the concentration on MINT subjects continues to increase. Financial aspects play a subordinate role due to scholarship programmes and free access to (higher) education. Access for children from families with low social status is also facilitated.

W2. **Strong application focus on MINT/strong restrictions on access:** Schools and universities are transforming themselves even more into pure training centers for industry, and the focus on MINT subjects is continuing to grow. Education is largely to be financed privately. The restrictions on access for children from families with low social status are becoming much stronger again. The general level of education rises less due to strong access restrictions compared to the variants with lower access restrictions.

W3. **Strong focus on general education/low access restrictions:** Since the need for interdisciplinary research is becoming increasingly evident in more and more research areas, (higher) schools are increasingly creating multidisciplinary courses that provide the necessary foundations for this. Financial aspects play a subordinate role due to scholarship programmes and free access to (higher) schools. Access for children from families with low social status is also facilitated.

[48] Hamann 2001: 'Bildung' in German human sciences: the discursive transformation of a concept. History of the Human Sciences, vol. 24, no. 5, p. 48 - 72
[49] Münch 2007: Die akademische Elite. Suhrkamp Publisher
[50] Equnet 2010: Evolving diversity - An overview of equitable access to Higher Education in Europe.
[51] Translators‘ note: MINT education focuses on mathematics, informatics, the natural sciences and technology.

National Factors / ”Cultural" Sector

X. Attitude of the population towards the transformation of the energy system / NIMBY

The transformation of the energy system is currently experiencing acceptance, although strong “Not-in-my-backyard” (NIMBY) trends can certainly be observed.[52] [53] With respect to the narratives about the transformation of the energy system ("views", which are connected with the transformation of energy, e.g. "We ourselves have done this to the earth, we also have to 'straighten this out' again" or "The transformation of energy throws us back in international competition"), there is at the moment still no dominant trend recognizable.

X1. **Trend towards positive attitude:** The attitude of the population towards the energy system transformation remains positive. People are willing to bear the "costs" of the energy system transformation in order to stop climate change or mitigate its effects and want to set a good example worldwide. Narratives advocating the energy system transformation have more weight than negative ones. There is no strong NIMBY behavior because it is considered socially unacceptable with regard to the energy system transformation.

X2. **No trend discernible:** The attitude of the population towards the energy system transformation is positive, but there is no clear commitment to bear the associated implications. Positive and negative narratives about the energy system transformation compete with each other, no direction prevails as a general attitude. Especially where the necessity of investment for the energy system transformation is highly controversial among the social groups (e.g. with respect to which power lines are needed), NIMBY tendencies occur increasingly, impeding the implementation of infrastructural measures planned for the energy system transformation.

X3. **Trend towards negative attitude:** Abstractly, the energy system transformation is still advocated, but local or regional implications are predominantly rejected.[54] Negative narratives on the energy system transformation, experiences perceived as negative and fears associated with the energy system transformation steer the population's attitude towards the energy system transformation in a generally skeptical direction. People react to infrastructural measures with strong NIMBY tendencies.

[52] BDEW-Umfrage:
[53] Allensbach-Umfrage:
[54] Kaiser, G., Byrka, K. and Hartig, T. 2010: Reviving Campbell´s Paradigm for Attitude Research. Personality and Social Psychology Review 2010 14: 351

Y. Value orientation and economic design objectives

Values and value orientation are an essential element of culture[55] and can be described as the " perceptions of desirability ".[56] The function of culture resp. the social-cultural system is the regulation of interactions within a society by the social construction of symbol systems.[57] However, these symbol systems change in the course of social and cultural change and also influence the objectives of economic design.

Y1. **Trend towards materialism and productivity:** Material consumption plays a major role as a target and prosperity is primarily defined by it. The main objective of economic design is still the conventional material growth stimulated by competition.

Y2. **Trend towards sustainable materialism:** Material consumption still plays a role as a target, but is subordinated to the model of sustainability. This is also reflected in people's objectives for economic design, which is to develop in the direction of material growth with declining environmental pollution.

Y3. **Trend towards post-materialism:** Post-materialistic values such as self-realization, friendship and leisure continue to gain importance; the focus is on experience orientation and hedonistic consumption. Conventional growth as an objective should give way to qualitative growth in the economy, i.e. the development of prosperity without expanding material production.

Y4. **Trend towards differentiation:** There is a change towards further differentiation and individualization. Values such as productivity, material growth, experience orientation, general sense of community, etc. are equally represented in society and depend on the respective reference milieu. The same applies to the objectives of economic design, which, in the absence of a clear trend reversal, can develop towards different directions.

[55] Schwartz, S.H. 2006: A theory of cultural value orientations: Explications and applications. Comparative Sociology 5(2), p. 137 - 182.
[56] Kluckhohn, C. 1951: Values and Value Orientations in the Theory of Action. An Exploration in Definition and Classification". In: Toward a General Theory of Action. Ed. of Talcott Parsons and Edward A. Shils. Cambridge: Harvard University Press, 1951, p. 388 - 433.
[57] Münch, R. 1984

Z. Media Discourse

The media sector - broadcasters and publishers - has recently experienced a strong consolidation and concentration process. Many providers are responding to this by increasing the "tabloidization" of reporting.[58] [59] [60] Added to this is the increasing spread of new media, the use of which is only partly in competition with traditional media, which, however, form qualitatively new forms of communication and communitization, leading to a further increase in media and communication channels.

The possible future development will therefore be outlined on the basis of the dimensions of boulevard- vs. quality journalism and diversity vs. concentration of opinions.

Z1. **High diversity of opinion/strong tabloidization:** Concentration through acquisitions and mergers is counteracted by a steadily growing supply, so that a growing number of different media offerings is created. The competition between these is mainly conducted through emotionalizing and personalized reporting.

Z2. **High diversity of opinion/low tabloidization:** Concentration through acquisitions and mergers is counteracted by a steadily growing supply, so that a growing number of different media offerings is created. The competition between these is primarily conducted through investigative, but factual journalism. The demand for quality journalism is increasing and can also be monetarized.

Z3. **Low diversity of opinion/strong tabloidization:** The consolidation of the publishing industry and broadcasters will continue unabatedly. In this environment, new offers can hardly assert themselves or are quickly bought up. Competition between the remaining offerings is primarily driven by emotionalizing and personalized reporting.

[58] Koblinger, Dagmar 2002: Die Verlagsbranche im Wandel - ein empirischer Forschungsbericht. Munich, Germany.

[59] Commission staff working document: Media pluralism in the Member States of the EU. SEC (2007) 32, https://ec.europa.eu/information_society/media_taskforce/doc/pluralism/media_pluralism_swp_en.pdf

[60] Vīķe-Freiberga, Vaira et al. 2013: A free and pluralistic media to sustain European democracy. The Report of the High Level Group on Media Freedom and Pluralism. https://ec.europa.eu/information_society/media_taskforce/doc/pluralism/hlg/hlg_final_report.pdf

Passive Factors

a. Development of consumption -- Household appliances

Although in recent years household appliances in Germany have become more energy efficient, the electricity consumption caused by them has increased, which is influenced by various intervening factors such as number of appliances, household size, etc. Nevertheless, it is expected that the increasing efficiency of the appliances will lead to a reduction of the consumption caused by them in the long run. For 2050 the scenarios fluctuate between an annual reduction of the average household electricity consumption by approx. 0.6% per year and approx. 1.3% per year.[61][62]

a1. **Weak development of consumption:** The average household electricity consumption decreases until 2050 per year by 0.6%.

a2. **Strong development of consumption:** The average household electricity consumption decreases until 2050 per year by 1.3%.

[61] WWF 2009: „Modell Deutschland. Klimaschutz bis 2050: Vom Ziel her denken“. (p. 67, 185) https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Modell_Deutschland_Teil1.pdf

[62] DLR/UBA 2009: “Role and Potential of Renewable Energy and Energy Efficiency for Global Energy Supply” indicates a 70 % savings potential of the devices for the region, but no use.

b. Efficiency development -- passenger car (electrical)

In the case of electric vehicles, an increase in energy efficiency can be expected in the period under review, especially as these technologies are only slowly reaching the mass market. Both the distribution and the expected increase in efficiency of these vehicles are subject to different assumptions. It can be expected that a broad spread will also be closely related to efficiency.[63] [64] We therefore assume that there is a variant with lower penetration and lower efficiency and one with higher penetration and higher efficiency.

b1. **Weak efficiency development:** For the scenario, a weak increase in efficiency means a reduction in the specific consumption of electric vehicles of 0.8 % per year.

b2. **Moderate efficiency development:** A moderate increase in efficiency means a reduction in the specific consumption of electric vehicles of 1.7 % per year.

b3. **Strong efficiency development:** A strong increase in efficiency means a reduction in consumption of 2.1 % per year.

[63] Nitsch et al. 2012: „Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global". https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/leitstudie2011_bf.pdf

[64] Shell 2009: „Shell PKW-Szenarien bis 2030". Hamburg, Germany, https://www.shell.de/promos/media/shell-passenger-car-scenarios-2009/_jcr_content.stream/1455704838555/6046cfe553eefcd02a0537d98e10fa0fec1289e9/publications-2009shellmobilityscenarios.pdf

c. Efficiency development -- passenger car (combustion engine)

For a long time, increasing weight and stronger engines have prevented an increase in overall efficiency in the passenger car sector and have not allowed average consumption to fall. In recent years, however, average consumption has fallen. The scenarios considered therefore all assume that average consumption will continue to fall in the future, albeit at different rates. In general, a somewhat lower savings potential (0.8 - 1.55 % per year) is attested to diesel engines than to gasoline engines (0.8 - 1.75 % per year).[65] [66]

c1. **Weak efficiency development:** As the lower limit of a weak efficiency improvement, we therefore assume an average improvement of only 0.8% per year for both technologies.

c2. **Strong efficiency development:** Strong efficiency development means an annual reduction in average consumption of 1.55 % per year (diesel) or 1.75 % per year (gasoline).

[65] Nitsch et al. 2012: „Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global". https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/leitstudie2011_bf.pdf

[66] Shell 2009: „Shell PKW-Szenarien bis 2030". Hamburg, Germany, https://www.shell.de/promos/media/shell-passenger-car-scenarios-2009/_jcr_content.stream/1455704838555/6046cfe553eefcd02a0537d98e10fa0fec1289e9/publications-2009shellmobilityscenarios.pdf

d. Efficiency development -- Buildings (private)

With regard to climate protection targets, the current renovation rate and depth are insufficient to achieve the planned reduction in private household consumption. The energy efficiency of the residential buildings has a very strong influence on the private energy consumption, since approx. 3/4 of the direct final energy consumption is caused by heating. Since many measures therefore aim at increasing the renovation rate and energy efficiency, the continuation of the current trend represents the lower variant of this descriptor, as is also the case in the scenarios examined.[67] [68] [69] [70]

d1. **Weak efficiency development:** A low efficiency development means a continuation of the current practice with a renovation rate of approx. 1 % and a renovation depth of 30 %.

d2. **Moderate efficiency development:** A moderate efficiency development in this area would mean a slight increase in the restructuring practice observed in recent years. Approximately 1.5 % of residential buildings will then be renovated annually. The depth of renovation is 50%.

d3. **Strong efficiency development:** A strong efficiency development means a renovation rate of approx. 2 %, the renovation depth is 70 %.

[67] WWF 2009: „Modell Deutschland. Klimaschutz bis 2050: Vom Ziel her denken". https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Modell_Deutschland_Teil1.pdf

[68] Nitsch et al. 2012: „Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global". https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/leitstudie2011_bf.pdf

[69] Exxon 2012: Energieprognose 2012 - 2040. Deutschland. Erdgas: Brücken- oder Basisenergie? http://services.exxonmobil.de/downloads/Energieprognose_2012.pdf

[70] Shell 2011: Shell Hauswärme-Studie. https://www.shell.de/promos/media/shell-house-heat-study-2011/_jcr_content.stream/1455892952601/857e5cca7cb81a00c6d8b59ec4204576b25cfc07/shell-hauswaermestudie-2011.pdf

e. Efficiency development -- Industry

Energy intensity is often used as an indicator of the energy efficiency of an economy. It describes the amount of (primary) energy needed to produce one unit of GDP. Between 1990 and 2010, this unit improved by approx. 1.65 % per year for Germany, so that more GDP could be generated with less energy input.[71] For industrial production, the corresponding figure would be the final energy consumption of industry in relation to industrial production in euros.

In the literature there is a range of annual increases in efficiency of between approx. 1.2 % and 2.3 % per year[72] for the future development of this parameter.

e1. **Weak efficiency development:** This means a reduction of the energy intensity of industry by approx. 1 % per year.

e2. **Strong efficiency development:** This means a reduction of the energy intensity of the industry by approx. 2.3 % per year.

[71] Nitsch et al. 2012: „Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global“. pp. 59ff https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/leitstudie2011_bf.pdf

[72] WWF 2009: „Modell Deutschland. Klimaschutz bis 2050: Vom Ziel her denken“. https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Modell_Deutschland_Teil1.pdf

f. Efficiency development - GHD

Just like efficiency development in industry, efficiency for trade, services and commerce at the macro level is often described by energy intensity (€/MJ) or energy productivity (MJ/€). Between 1991 and 2012, energy productivity in the GHD sector in Germany increased on average by 1.51 €ct/MJ per year - or 1.5 % per year.[73] [74] [75]

Most energy scenarios assume a stronger increase in energy productivity by 2050 also in the reference scenarios than in the last two decades. Overall, the scenarios vary from 2 % to 3.4 %.[76] [77] [78]

f1: **Weak efficiency development:** A weak efficiency development means a continuation of the current trend and an increase in energy productivity of approx. 1.5% per year.

f2: **Moderate efficiency development:** This means an annual increase in energy productivity of approx. 2.5 % per year.

f3: **Strong efficiency development:** Strong efficiency development means an annual increase in energy productivity of approx. 3.4 % per year.

[73] Federal Ministry for Economic Affairs and Energy (BMWi) energy data, April 2014; https://www.bmwi.de/Redaktion/EN/Artikel/Energy/energy-data.html)

[74] Statistisches Bundesamt (destatis), https://www.destatis.de/EN/Home/_node.html

[75] AG Energiebilanzen e.V. (AGEB) 2013: Ausgewählte Effizienzindikatoren zur Energiebilanz Deutschland, https://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=eefa-ageb-effizienzindikatoren_zur_energiebilanz_orange_2012_16_09_2013.pdf

[76] Nitsch et al. 2012: „Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global". https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/leitstudie2011_bf.pdf

[77] WWF 2009: „Modell Deutschland. Klimaschutz bis 2050: Vom Ziel her denken". https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Modell_Deutschland_Teil1.pdf

[78] Schlesinger et al. 2010: BMWi Szenarien für das Energiekonzept der Bundesregierung.

g. Expansion district heating

In Germany the heat supply of most households is solved by object-bound plants. Nearly 13 % of households in Germany were supplied by local and district heating in 2013, in 1995 it was about 12 %.[79] However, higher efficiency values can be achieved here in comparison to object-related heat supply.

g1. **No increased expansion of local and district heating networks:** The proportion of buildings supplied by local and district heating continues to rise only very slightly.

g2. **Increased expansion of local and district heating networks:** There is a move away from the practice of object-related heat supply and local and district heating networks are being strongly expanded.

[79] AG Energiebilanzen e.V. (AGEB) 2013: Energieverbrauch in Deutschland im Jahr 2013. https://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=ageb_jahresbericht2013_20140317.pdf

h. Investments in new vehicle concepts and infrastructure

The composition of the vehicle fleet has a significant influence on the achievement of the CO_2 reduction targets. Whether in the future the mileage will be increasingly replaced by electric or hybrid cars, or to what extent fossil fuels will be replaced by bio and other RE-based fuels, depends on the extent of investment in technology development and the development of the associated infrastructure. The future composition of the vehicle fleet also depends on the development of energy demand in private transport.

h1. **Low investment:** If investments in vehicle concepts are made only to a small extent, the share of cars with alternative, CO_2-free drive systems in the passenger car fleet will reach about 20% by 2050.

h2. **Moderate investment:** If investments are made on a medium scale, by 2050 about half of the entire passenger car fleet will have an alternative, CO_2-free drive.[80] Fossil fuels will gradually be replaced by renewables.

h3. **High investments:** If high investments are made in new vehicle concepts, up to 100% E-vehicles[81] and fuel cell cars powered by hydrogen or methane[82] can be brought into the passenger car market by 2050. Hydrogen/methane engines are also partly used in truck transport.

[80] Greenpeace: energy [r]evolution. A sustainable world energy outlook. Report 3rd edition 2010 world energy scenario, p. 41; https://www.greenpeace.de/sites/www.greenpeace.de/files/Energy-Revolution-0910_gpi_E_R__full_report_10_lr_0.pdf, Nitsch et al. 2012: Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. p. 66, https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/leitstudie2011_bf.pdf; Umweltbundesamt (UBA) 2010: Energieziel 2050. 100% Strom aus erneuerbaren Quellen, p. 29, https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/energieziel_2050.pdf

[81] Greenpeace: energy [r]evolution. A sustainable world energy outlook. Report 3rd edition 2010 world energy scenario, p. 42

[82] Nitsch et al. 2012: „Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global“. p. 66, https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/leitstudie2011_bf.pdf; ForschungsVerbund Erneuerbare Energien (FVEE) 2010: Energy Concept 2050 for Germany with a European and Global Perspective. A vision for a sustainable energy concept based on energy efficiency and 100% RE, p. 38f, https://www.fvee.de/fileadmin/publikationen/Politische_Papiere_FVEE/10.06.Energy_Concept_2050/EK2010_EN.pdf

i. Housing trends

Various things can be read from the living trends. On the one hand, there is information about how much space needs to be heated or air-conditioned and therefore also about how high the future energy demand will be. On the other hand, the living space per capita (2010: 42.4 m²) also provides information about the standard of living of people in Germany in 2050.

i1. **Small increase:** A small increase in living space could mean that the average living space per capita is 50 m².[83]

i2. **Moderate increase:** If the living space of Germans rises moderately by 2050, people will live on an average of approx. 55 m².

i3. **Strong increase:** If a strong increase in living space is to be expected by 2050, the living space per capita will be just below 60 m².[84]

[83] Nitsch et al. 2012: Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. p. 47, https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/leitstudie2011_bf.pdf

[84] DLR / IFEU / Wuppertal-Institut 2004 (2000: 38,4 m²; 2010: 45 m²)

j. Expansion of renewables (heat)

The amount of investment that will be made in expanding renewables for heat generation determines the share of renewables (for heat generation) in the energy mix in 2050. The contribution that the heating sector can make to climate protection through the use of renewable energies is enormous. The demand for renewable energy for heat depends largely on the final energy consumption, which is influenced by factors such as the renovation of buildings, the renewal cycle of heating systems, etc. The demand for renewable energy for heating depends on the final energy consumption. In 2012, 154 TWh of heat was generated from renewables.[85] This corresponds to an average increase of around 9 TWh/year in the decade 2002 - 2012.

j1 **Small expansion:** If only small investments are made, by 2050 approx. 250 TWh of heat can be generated from renewable sources, predominantly for space heating and hot water.[86] This corresponds to an average increase of around 2.5 TWh/year.

j2 **Strong expansion:** If large investments are made in the expansion of renewables for heat generation (including process heat), around 400 TWh can be generated from renewables in 2050.[87] This corresponds to an average increase of around 6.5 TWh/year.

j3. **Very strong expansion:** If very strong investments are made in the expansion of renewables for heat supply, up to approx. 500 TWh of heat can be generated from renewables in 2050 (including process heat and heat from renewables-based electricity).[88] This corresponds to an average increase of around 9 TWh/year.

[85] Federal Ministry for Economic Affairs and Energy (BMWi) energy data, April 2014; https://www.bmwi.de/Redaktion/EN/Artikel/Energy/energy-data.html)

[86] According to Fahl et al. 2009, p. 189

[87] Nitsch et al. 2012: Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. p. 62, https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/leitstudie2011_bf.pdf

[88] ForschungsVerbund Erneuerbare Energien (FVEE) 2010: Energy Concept 2050 for Germany with a European and Global Perspective. A vision for a sustainable energy concept based on energy efficiency and 100% RE, p. 38, https://www.fvee.de/fileadmin/publikationen/Politische_Papiere_FVEE/10.06.Energy_Concept_2050/EK2010_EN.pdf; Greenpeace: energy [r]evolution. A sustainable world energy outlook. Report 3rd edition 2010 world energy scenario, p. 4: 475 TWh/year in 2050

k. Rebound in individual energy consumption

The phenomenon of rebound is referred to here when, for example, "the same good is used (or produced) more, so that energy efficiency does not [or only to a lesser extent, the author's note] come into play".[89]

Increases in energy efficiency are often seen as a kind of patent solution for reducing energy consumption. The phenomenon that the energy savings made possible by efficiency improvements are only partially or not at all realized is described by the term rebound effect.[90] This means, for example, that a household replaces its old television with a more efficient but larger one and/or uses it more frequently. A technical efficiency increase of e.g. 30% for a device does not necessarily lead to an absolute energy saving of 30% in practical use. The rebound effect thus refers to a behavioral reaction in connection with an increase in technical efficiency.[91] The behavioral change can also cause a "negative" rebound if users buy a more efficient car, for example, and consider this to be an incentive to get used to a more fuel-efficient driving style. Then the technically expected energy savings would even be exceeded.

Rebound refers here to consumer behavior in the areas of mobility, the use of electricity by e.g. electrical appliances, lighting, etc. as well as space heating.

k1. **Trend towards no rebound:** The saving of energy made possible by efficiency increases in the consumer technology sector is not counteracted by an expansion of use and thus is largely realized. Behavioral patterns occur here that lead to both low rebound and negative rebound and thus largely balance each other out.

k2. **Trend towards moderate rebound:** The energy savings made possible by efficiency improvements in consumer technology are leading to moderate increases in use and are therefore only partially being realized.

k3. **Trend towards strong rebound:** The saving of energy made possible by efficiency increases in the area of consumer technology causes strong expansion of use and can therefore largely not be realized. Some people consume even more energy than before the increase in efficiency.

[89] Deutscher Bundestag 2014: Aktueller Begriff. Der Rebound-Effekt: Störendes Phänomen bei der Steigerung der Energieeffizienz. Wissenschaftliche Dienste Nr. 16/14 05. Juni 2014; https://www.bundestag.de/resource/blob/282726/85e2970ac3cda746a05541a0269eda69/der-rebound-effekt--stoerendes-phaenomen-bei-der-steigerung-der-energieeffizienz-data.pdf

[90] see footnote 89

[91] Santarius, Tilman (2014): Der Rebound-Effekt. Ein blinder Fleck der sozial-ökologischen Gesellschaftstransformation Rebound Effects: Blind Spots in the Socio-Ecological Transition of Industrial Societies. In: GAIA 23 (2), p. 109-117. http://www.santarius.de/wp-content/uploads/2014/06/Der-blinde-Fleck-Rebound-Artikel-in-GAIA-2014.pdf