ENERGY SUPPLY AND SUSTAINABLE DEVELOPMENT: THE NEED FOR NUCLEAR POWER

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Mr. Chairman, Ladies and Gentlemen,

We are meeting here today to celebrate the founding of a new corporation: FRAMATOME Advanced Nuclear Power. This merger of FRAMATOME and Siemens Nuclear Power is an important event from the point of view of industrial and energy policy since a product is being offered that will become increasingly valuable as we tackle the demands of the 21st century.

Given the many and various problems the nuclear energy industry has encountered over the past decades and which still remain to be overcome in some countries, this may strike some of you as being an optimistic statement. This is why I will attempt to substantiate and underpin my positive attitude during the course of my lecture.

The Challenges

If the trends of the world’s past history continue in the future, the prospects for the development of mankind include inconceivable catastrophes triggered off by hunger and poverty, by the destruction of the natural foundations of life or by man-made destabilisation of the earth's climate.

These challenges are all directly related to the energy supply system

- since procuring an increasing amount of energy services is a necessary precondition for overcoming hunger and poverty and even limiting the global population increase,

- since 50 % of anthropogenic green house gas emissions are released by the energy system;

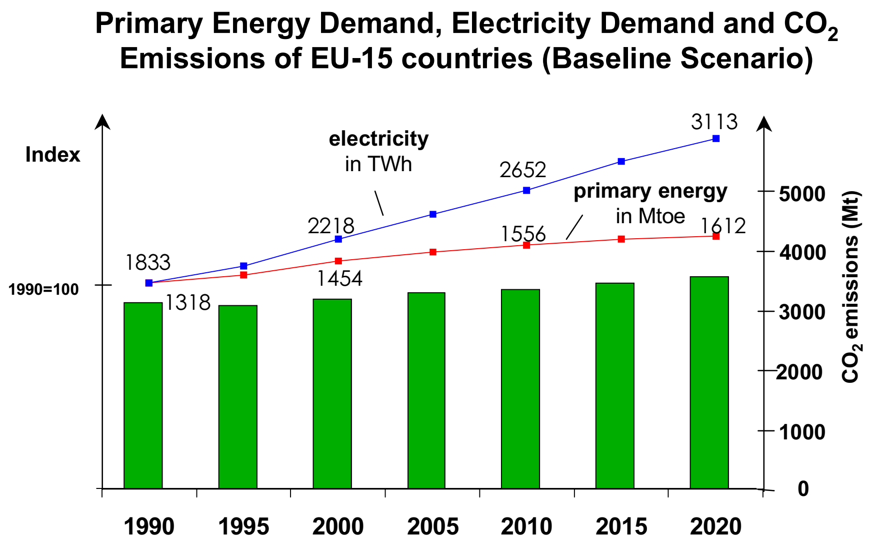
- since today's energy system consumes the major share of finite fossil resources and is the single most important source of air pollution.

As far as these challenges are concerned there is widespread agreement in society. But the degree of consensus dwindles with respect to the targets and models to be achieved and controversial, sometimes even contradictory opinions exist amongst important groups in society – at least in the industrialised countries – on the course to be taken. A lack of consensus prevails not so much on the end but on the means.

Resolving the 'trilemma' among the economic aspirations of a rapidly expanding global population, the available resources, and the environment, is one of the most critical challenges of the twenty-first century. The provision of electricity is of central importance for both economic growth and social development. Although, as can be seen from Figure 1, we can expect a decline in the energy intensity of the

European economies, indicating a further uncoupling of economic growth and primary energy requirement, the electricity demand in the EU is still expected to grow from about 2000 TWh in 1995 to more than 3100 TWh in 2020, which is an increase of more than 50 % [European Commission, 1999 a]. On the other hand there is an obvious need to reduce the environmental impacts of electricity production and to avoid unacceptable impacts on the climate system. In spite of significant efforts towards the reduction of CO_2-emissions in all the relevant sectors of our economy, CO_2-emissions in the countries of the European Union are projected to increase annually by 0.6 % in the 1995 to 2020 period from 3037 Mt in 1995 to 3508 Mt in 2020 [European Commission, 1999 a]. Under business-as-usual assumptions fossil fuels are projected to still dominate the energy supply systems in the next 20 years, resulting in a strong rise in global carbon dioxide emissions.

Figure 1:



source: Energy in Europe: European Energy Outlook to 2020, 1999

Among other aspects, in particular the risks and uncertainties of the global warming problem have led to a resurgence of interest in sustainable development. Since the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 the concept of sustainable development as a model of environmentally compatible and socially acceptable development of human activities has gained widespread attention. Despite this growing interest, sustainable development is often broadly defined, so that the concept is used by different people to mean very different things. The energy debate being a prominent example.

To prevent the concept of sustainability from becoming a mere buss-word, there is a need to define what the concept of sustainable development means for the energy system in concrete terms and how it can provide guidance on the comparative assessment of energy supply options with regard to a sustainable provision of energy.

THE CONCEPT OF SUSTAINABLE DEVELOPMENT: WHAT DOES IT MEAN FOR THE ENERGY SYSTEM?

According to the Brundtland Commission, and the Rio Declarations, the concept of ‘sustainable development’ embraces two intuitively contradictory demands, namely the sparing use of natural resources and further economic development. The Brundtland Commission defines sustainable development as one which meets the needs of the present generation without compromising the ability of future generations to meet their own needs.

Figure 2:

The Brundtland Commision's Definition of Sustainable Development

"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

Even if this definition has arisen against a background of environmental and poverty problems, it nevertheless represents an ethically motivated claim which is derived from considerations of fairness with future generations in mind.

The challenge is to simultaneously help to deliver economic prosperity, to reduce and eventually eliminate poverty, to provide environmental quality and social equity and to maintain the natural foundations of life.

Therefore, the aim of sustainable development is to bequeath future generations with a stock of natural resources which will enable them to satisfy their needs at least at the level we enjoy today. This general definition of sustainability, which is acceptable to many, is not very specific about how we can guarantee satisfying the needs of future generations, for example with reference to the energy supply. It is both vague and open-ended and therefore leaves room for different interpretations.

Any attempt to define the concept of sustainability in concrete terms can only be sound if – as far as the material-energetic aspects are concerned – it takes the laws of nature into account. In this context the second law of thermodynamics which the chemist and philosopher Wilhelm Ostwald called “The law of happening” [Das Gesetz des Geschehens] acquires particular significance.

The fundamental content of the second law of thermodynamics is that life and the inherent need to satisfy requirements is vitally connected with the consumption of workable energy and available material.

Within the context of defining the concept of sustainability in concrete terms the need to limit ecological burdens and climate change can certainly be substantiated. It becomes more difficult when confronted with the question of whether the use of finite energy resources is compatible with the concept of "sustainable development", because oil and natural gas and even the nuclear fuels which we consume today are not available for use by future generations. This then permits the conclusion that only the use of "renewable energy" or "renewable resources" is compatible with the concept of sustainability.

But this is not sound for two reasons. On the one hand the use of renewable energy, e.g. of solar energy, also always goes hand in hand with a claim on non-renewable resources, e.g. of non-energetic resources and materials which are also in scarce supply. And, on the other hand, it would mean that non-renewable resources may not be used at all – not even by future generations.

Given that it is, therefore, obviously impossible to pass on un-changed the non-renewable resource base, the important thing within the meaning of the concept of sustainable development is to bequeath to future generations a resource base which is technically and economically usable and which allows their needs to be satisfied at a level at least commensurate with that which we enjoy today.

However the energy and raw material base available is fundamentally determined by the technology available. Deposits of energy and raw materials which exist in the earth's crust but which cannot be found or extracted in the absence of the requisite exploration and extraction techniques or which cannot be used economically cannot make any contribution towards securing the quality of life. It is therefore the state of the technology which turns valueless resources into available resources and plays a joint part in determining their quantity.

As far as the use of limited stocks of energy is concerned this means that their use is compatible with the concept of sustainability as long as it is possible to provide future generations with an equally large energy base which is usable from a technical and economic viewpoint. Here we must note that in the past the proven reserves, i.e. energy quantities available technically and economically, have risen despite the increasing consumption of fossil fuels. Moreover, technical and scientific progress has made new energy bases technically and economically viable, for instance nuclear energy and part of the renewable energy sources.

As far as the use of the environment is concerned, the debate should take greater note of the fact that environmental pollution, including those connected with today’s energy supply, are primarily caused by anthropogenic flows of substances, by substance dispersion i.e. the release of substances into the environment. It is not, therefore, the use of the working potential of energy which pollutes the environment but the release of substances connected with the respective energy system, for instance the sulphur dioxide or carbon dioxide released after the combustion of coal, oil and gas. This becomes clear in the case of solar energy which, with the working potential – solar radiation – it makes available is, on the one hand, the principle source of all life on earth but is also, on the other hand, by far the greatest generator of entropy, because almost all of the sun's energy is radiated back into space after it has been devalued as heat at the ambient temperature. Since its energy, the radiation, is not tied to a material energy carrier, the generation of entropy does not produce any pollution in today's sense of the word. This does not, of course, exclude the release of substances and assciated environmental pollution in connection with the manufacture of the solar energy plant and its equipment.

The facts addressed here are of such particular significance because this entails the possibility of uncoupling the consumption of energy and the pollution of the environment. The increasing use of working potential (energy) and a reduction in the burdens on the climate and the environment are not, therefore, a contradiction in terms. It is the emission of substances that have to be limited, not the energy flows themselves, if we want to protect the environment.

In addition to expanding the resource base available, the economical use of energy or rather of all scarce resources is, of course, of particular significance in connection with the concept of "sustainable development". The efficient use of resources in connection with the supply of energy does not only affect energy as a resource since the provision of energy services also requires the use of other scarce resources including, for instance, non-energetic raw materials, capital, work and the environment.

The efficient use of all resources as can be derived from the concept of sustainability also corresponds to the general economic principle, however. Both allow for the conclusion that an energy system or an energy conversion chain for the provision of energy services is more efficient than another if fewer resources, including the resource environment, are utilized for the energy service.

In the economy costs and prices serve as the yardstick for measuring the use on scarce resources. Lower costs with the same use mean an economically more efficient solution which is more considerate on resources. The argument that can be raised against using costs as a criterion for evaluating energy systems is that the external effects of environmental damage for instance are not currently incorporated in the cost-calculations. This circumstance can be remedied by an internalisation of external costs. This allows the conclusion to be drawn that costs – and by that I mean full costs which include and take account of external effects – are a suitable yardstick for measuring the utilisation of scarce resources. This means that they also constitute an appropriate method for assessing energy techniques with regard to the concept of sustainability and it would be appropriate if, in this function, they were again to be afforded greater significance in the energy policy debate.

Furthermore, cost efficiency is also the basis for a competitive energy supply in order to secure the energy side of economic development and adequate employment and it is also the key to avoiding intolerable climate change. Both of these issues are central aspects of the concept of “sustainable development”.

Following this clarification of the concept of sustainable development with regard to the supply of energy I would now like to examine various electricity production options as regards their contribution towards a sustainable development of energy supply.

The assessment will be based on a set of sustainable development indicators, including emissions to the environment, the requirement of both energetic and non-energetic non-renewable resources, health impacts and economic performance.

The approach of Life Cycle Assessment (LCA) provides a conceptual framework for a detailed and comprehensive comparative evaluation of electricity supply options with regard to these sustainability indicators. Full scope LCA considers not only the direct emissions from power plant construction, operation and decommissioning, but also the environmental burdens and resource requirements associated with the entire lifetime of all relevant upstream and downstream processes within the energy chain. This includes exploration, extraction, fuel processing, transportation, waste treatment and storage. In addition, indirect emissions originating from material manufacturing, the provision and use of infrastructure and from energy inputs to all up- and downstream processes are covered. As modern technologies increasingly tend to reduce the direct environmental burdens of the energy conversion process, the detailed assessment of all life cycle stages of the fuel chain is a prerequisite for a consistent comparison of technologies with regard to sustainability criteria.

I would now like to discuss some results of a detailed life cycle assessment with respect to some of the most important electricity generation options which are considered as representative for current and near-future technologies operated in Germany or Western Europe.

LCA RESULTS – A FIRST COMPARISON OF ENERGY SYSTEMS WITH A VIEW TO SUSTAINABILITY

The following figures will summarise results for some of the key impact categories. Although based on our present level of knowledge this is not a complete and comprehensive comparison of all the indicators that are important from the point of view of sustainability, but it does provide an initial indication of the potential contribution of specific electricity supply options to a future sustainable energy system.

Cumulative energy requirements

The generation of electricity is associated with partly quite intensive energy consumption by power plant construction, and – in the case of fossil and nuclear energy sources – also by fuel supply and waste treatment. The cumulative energy requirement as shown in the next Table for different power generation systems includes the primary energy demand for the construction and decommissioning of the power plant as well as for the production and supply of the respective fuel. The energy content of the fuel input is not included in the figures.

Table 1:

Cumulative energy requirement (CER)
and energy payback periods (EPP)

	CER without fuel [kWh_{Prim} / kWh_{el}]	EPP [months]
Coal	0.29	3,5
Lignite	0.17	2,7
Gas CC	0.16	0,8
Nuclear	0.08	2,9
PV poly (amorph)	1.24 (0.67)	140 (76)
Wind (5,5 m/s)	0.07	6,4
Hydro	0.04	10,9

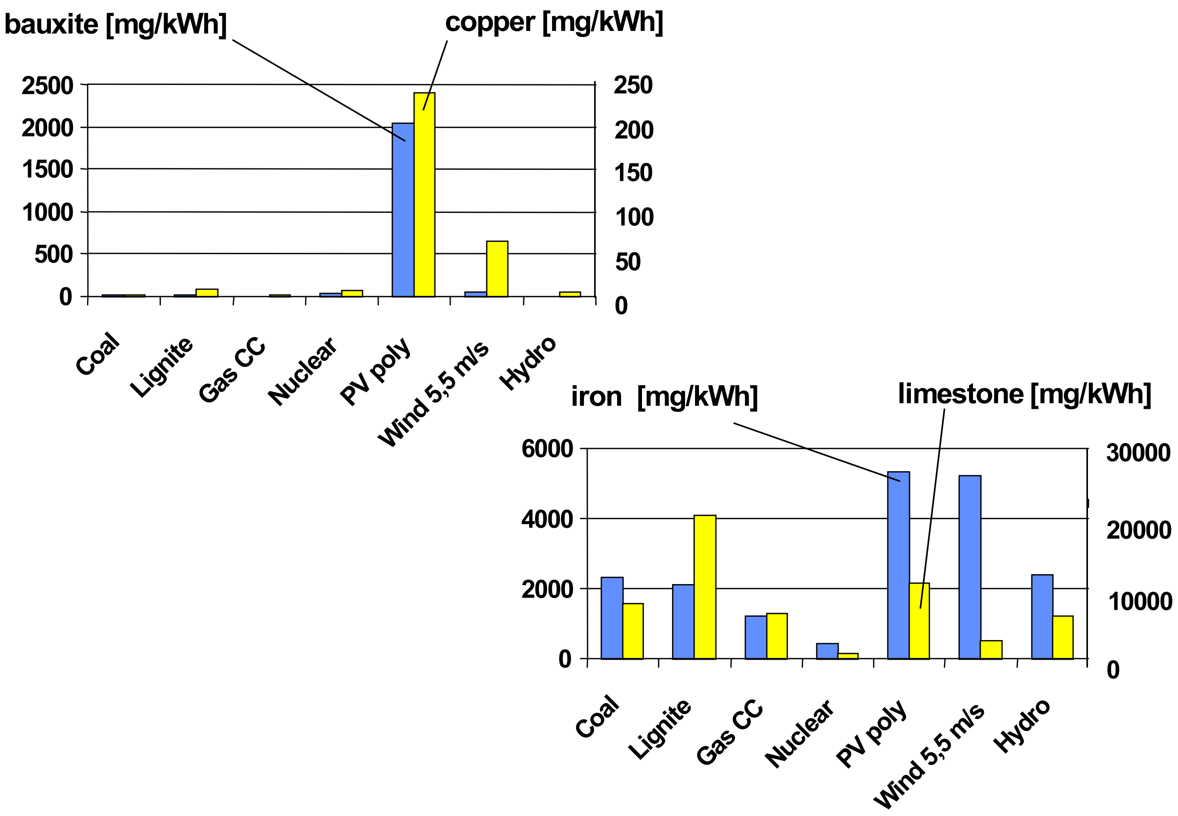
The indirect primary energy input per produced kWh of electricity for hydro, wind and nuclear systems is in the range of 0,04 to 0,08 kWh. For natural gas and coal the necessary energy input per produced unit of electricity is in the range of 0,16 to 0,29 kWh which is basically determined by the energy required for the extraction, transport and processing of the fuel. The corresponding figures for today's photovoltaic systems are 0,67 to 1,24 kWh. This is also reflected in the energy amortization time which is approximately 6 to 12 years in the case of photovoltaic systems using today's technology and is by far the longest compared with any of the other systems.

Raw material requirements

Electricity production involves consumption of non-energetic raw materials such as iron ore, copper ore, bauxite or limestone. Sustainability also means the efficient use of such resources.

The next figure shows the cumulated resource requirements of the power generation systems considered here for selected materials. It covers the raw material requirements for power plant construction, fuel supply, and for the supply of other raw materials e.g. limestone for the operation of flue gas desulphurisation facilities. The table only includes a small part of the various raw materials required and is therefore not a complete material balance. However, results indicate that the relatively small energy density of solar radiation and of the wind leads to a comparatively high material demand. This high material intensity for wind and solar energy is an important aspect with regard to the generation costs.

Figure 3: Total Life Cycle Raw Material Requirement

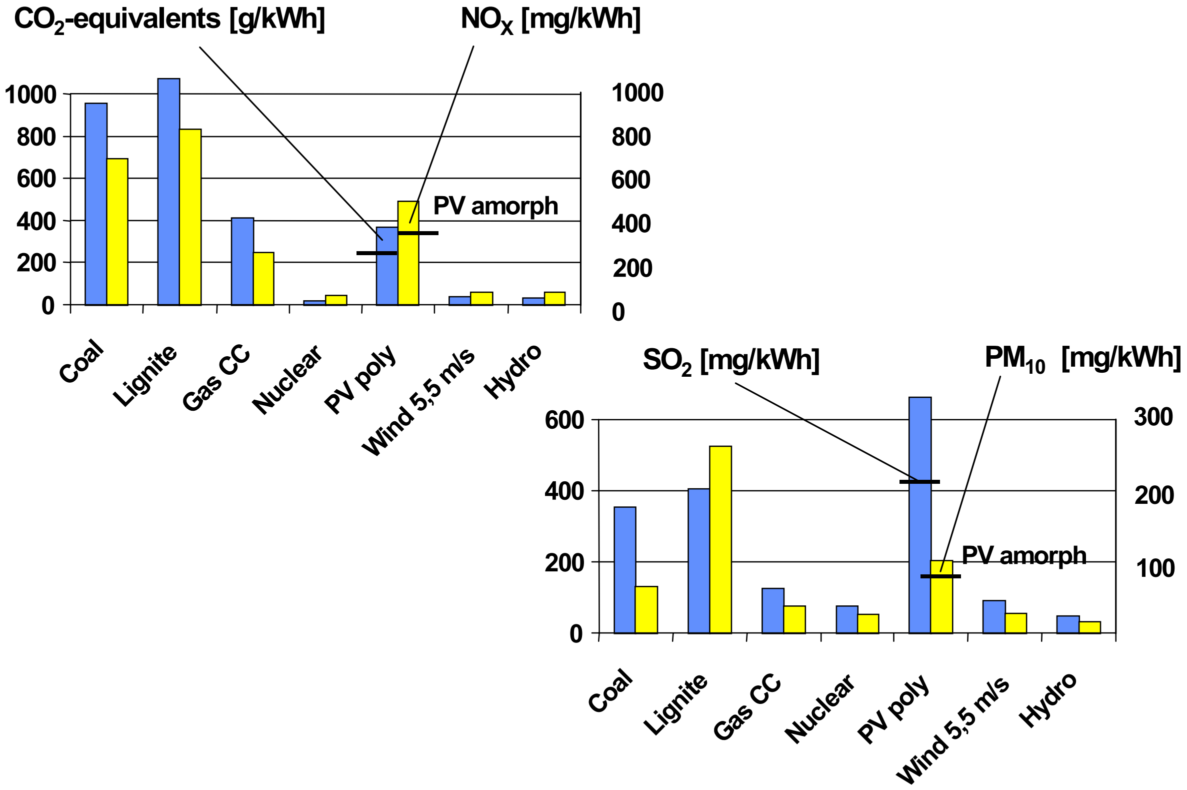


Pollutant Emissions

The next figure compares the cumulative emissions of selected pollutants of the power generation systems considered, taking into account the solid fossil fuels (hard coal and lignite) is characterised by the highest emissions of airborne pollutants per unit of electricity, while emissions from the nuclear system, hydropower and wind are comparatively low. Electricity generation from natural gas causes emissions that are significantly lower than those from coal-fired systems. Although there are no direct emissions from the electricity generation stage, the high material requirements for the production of PV panels result in cumulative CO_2 and NO_x emissions of the photovoltaic fuel chain that are close to those of the gas fuel chain and far higher as SO_2 and particulates are concerned.

It might be mentioned that the indirect emissions from material supply and component manufacturing are determined to a great extent by the emissions of the respective energy mix. Due to the high proportion of fossil energy in the German and European electricity mix, results shown in this figure are not directly applicable to other countries with a different energy mix.

Figure **4:** Total life cycle emissions

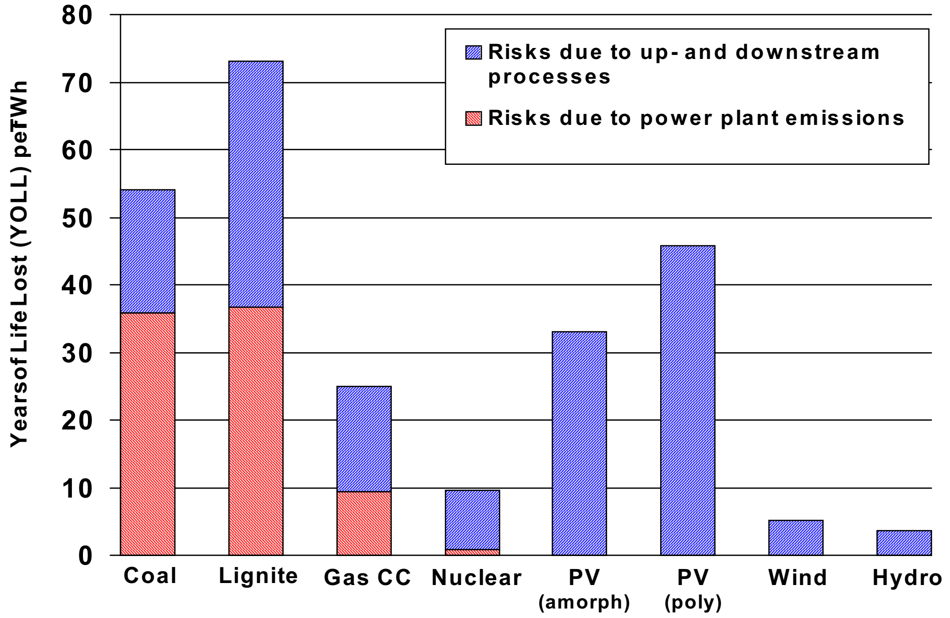


Human health risks

Electricity generation from fossil fuels, nuclear energy or renewable energy sources leads to an increased level of air pollution, or to an increased exposure of the population to ionising radiation, which in turn might cause an increased risk to the health of the exposed population. Using the emissions from the life cycle assessment as a starting point, health risks resulting from the operation of the energy systems considered here are assessed following a detailed impact pathway approach [Krewitt et. al., 1998]. For the quantification of health effects from pollutants relevant for fossil energy systems (fine particles, SO_2, Ozone) dose-effect models have been derived from recent epidemiological literature [European Commission, 1999 b]. The risk factors recommended by the International Commission on Radiological Protection (ICRP) are used to estimate effects from ionising radiation. The application of the ICRP risk factors to the very small individual dose resulting from long term and global exposure is, however, a matter of particular uncertainty and might lead to an overestimation of effects. Results of the risk assessment are summarised in the next Figure. The increased death risk is presented as the loss of life expectancy in Years of Life Lost (YOLL) per TWh.

This Figure shows that electricity generation from coal and lignite lead to the highest health risks of the power generation systems considered, while power generation from nuclear systems, wind and hydro energy is characterised by the lowest risk. Due to the high emissions from the material supply, risks from photovoltaic systems are higher than the risks from natural gas-fired power plant. Results for the nuclear fuel chain include the expected value of risk from beyond design nuclear accidents, which is small compared to the importance of major nuclear accidents in the public discussion. However, the expected value of risk is not necessarily the only parameter determining the acceptability of a technology. Different evaluation schemes that take into account risk aversion or a maximum tolerable impact might lead to a different ranking of technologies.

Figure 5 Health risks of energy systems



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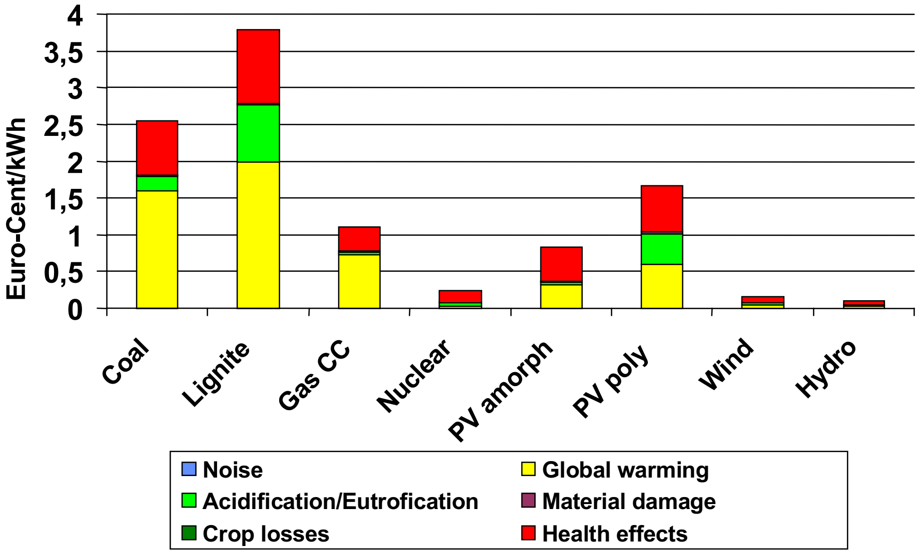
External costs

It is well accepted now that health impacts and environmental damage due to air pollution cause economic losses which are not accounted for in the electricity price (so called external costs). According to neo-classical welfare economics, external costs have to be internalised, i.e. added to the price of electricity, to achieve a full picture of the consumption of scarce resources. While uncertainties in the quantification of external costs are still relatively large, the next figure summarises external cost estimates that are quantified on the basis of the current state of the art, which is expected to support at least a quite robust ranking of energy technologies according to their environmental impacts.

External costs resulting from impacts on human health, agricultural crops, building materials and noise nuisance are considered as quantifiable with a reasonable level of uncertainty, but impacts on ecosystems and in particular potential impacts from global climate change are hardly quantifiable based on current knowledge, so that an economic valuation of the potential impacts is not possible. In these cases, marginal abatement costs for achieving policy-based environmental targets (German CO_2-reduction targets in the case of global warming, and SO_2- and NO_x-targets derived from the European Commission's strategy to combat acidification for ecosystem protection) are used to give a rough indication of the potential damage costs.

The figure shows that the quantifiable external costs are highest for the coal and lignite-fired power plants and lowest for electricity generation from nuclear systems, wind, and hydropower. External costs associated with natural gas are lowest among the fossil chains and are dominated by the global warming impacts. The external cost of current photovoltaic systems are of the same order of magnitude as for electricity produced by natural gas.

Figure 6: External Costs of Energy Systems



Acidification/Eutrofication: Valuation based on marginal abatement costs required to achieve the EU "50%- Gap Closure" target to reduce acidification in Europe

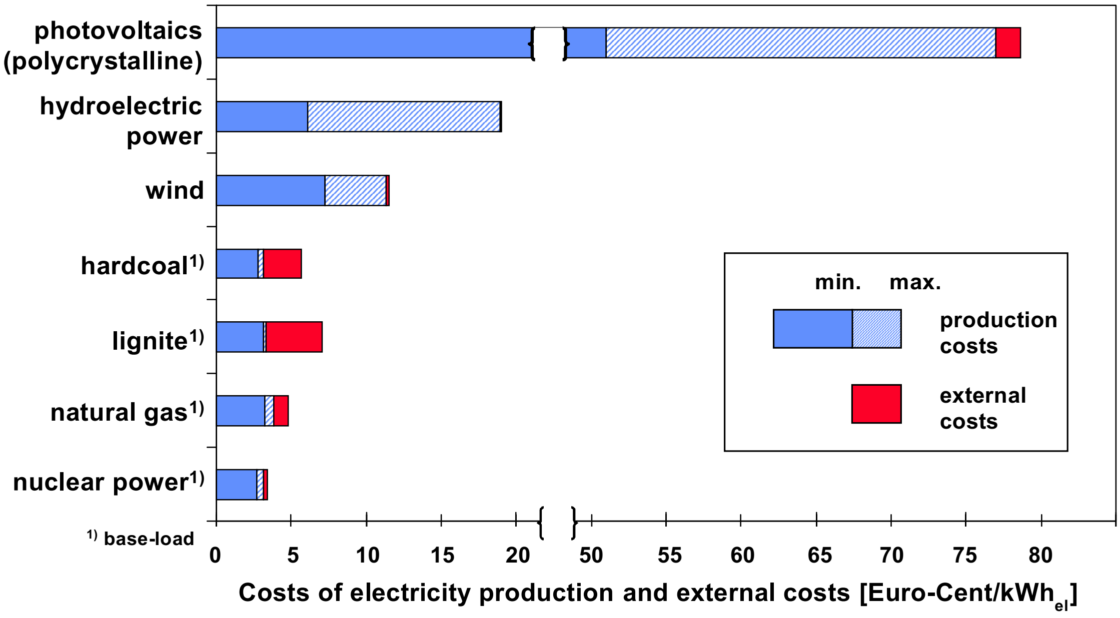
Global warming: Valuation based on marginal CO_2-abatement costs required to reduce CO_2-emissions in Germany by 25% in 2010 (19 Euro/tCO_2) 16.1.2001

Power generation costs

Costs in general are considered as a helpful indicator for measuring the use of sparse resources. It is thus not surprising that a high raw material and energy intensity is reflected in high costs. The power generation costs shown in the next Figure indicate that power generation from renewable energies is associated with higher costs – much higher in the case of solar energy – than those resulting from fossil-fired or nuclear power plants. However, as discussed above, the private costs alone do not fully reflect the use of scarce resources. To account for environmental externalities, external costs have to be internalised, i.e. added to the private generation costs. The Figure shows that the external costs resulting from the electricity generation of fossil fuels amount to about 30 % (natural gas) to 50 % (coal and lignite) of the generation costs, while for the other technologies the external costs are only a small proportion of generation costs. The internalisation of external costs might lead to competitiveness of some wind and hydropower sites compared to fossil fuels, but does not affect the cost ratios between the renewable and the nuclear systems. On the other hand it is obvious, that the full internalisation of environmental externalities would improve the competitive advantage of nuclear energy.

I feel that full costs are an appropriate yardstick for measuring the use of sparse resources and for assessing energy technologies with reference to sustainability. In this respect they should gain greater importance in the energy debate.

Figure 7: Costs of electricity production



The results of energy and raw material requirements, life cycle emissions, risks and both external and generation costs discussed so far are based on the characteristics of current technologies. It is expected that technical development will result in a further reduction in costs and in the environmental burdens of power generation. However, this applies to all the power generation technologies considered here.

CONCLUSION

Mr. Chairman, Ladies and Gentlemen, allow me to conclude:

Sustainable development basically means not depriving future generations of the opportunities for life and development. Some important conclusions for achieving an energy supply system which satisfies the concept of sustainable development are that:

- The use of limited stocks of energy is compatible with the concept of sustainability provided that we can guarantee future generations a technically and economically viable energy base which is at least of the same size.

- The use of scarce resources, including the environment as a resource, is decisive when assessing the sustainability of energy systems. The full costs (generation costs plus external costs) should be considered as a helpful indicator for assessing the contribution of power generation technologies to a sustainable energy system.

The technical progress made possible by increasing knowledge, which contributes to expanding the technically and economically exploitable raw materials and energy resources on the one hand and, on the other hand, allows a further uncoupling of economic development and the use of resources, will play a key role in achieving sustainable development.

A life-cycle-based evaluation employing a variety of sustainability criteria clearly shows that nuclear energy is an attractive source of low-cost electricity that can foster economic development and reduce greenhouse gas emissions cost effectively while broadening the available energy resource base for the generations to come.

Low total material requirements and the total energy requirements of nuclear electricity production are indications of the rational use of scarce resources in comparison with other electricity technologies.

Estimates of health risks including those of severe accidents indicate that nuclear power, when constructed and operated according to present safety standards, is associated with health impacts that are in the lower range of all electricity systems.

Nuclear energy combines economic, resource, climatological and environmental attractiveness making a sustainable electricity supply system a practically feasible and economically affordable target for a large number of countries in the world.

Much of the energy dilemma we are faced with hinges on the fact that essential scientific, technical and economic facts needed to provide a sound base for an energy policy aiming at sustainability are not used, but ignored.

If the world is serious about sustainable energy provision and decarbonising the global energy economy, nuclear power will be part of the solution.

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