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Long term scenarios and options for sustainable energy systems and for climate protection: A short overview

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Abstract

Within one decade a fundamental choice will have to be made: Should the energy system follow the historical trends of risky and unsustainable energy use patterns? Or should it take the course towards sustainable development and climate protection, giving top priority to energy efficiency and to a broad mix of renewable energies? Both roads are technically feasible. "Back-casting"-scenarios could help to answer the question, what technological options are available for climate protection and how societal goals can be achieved in a cost-effective way. Lessons learned from world energy scenarios and possible implementation options will be discussed. A case study of the German Parliament´s Enquete Commission on Sustainable Energy Systems will be taken as illustration. The analysis shows that sustainable energy systems can be financed and that economic growth can be decoupled from absolute levels of non-renewable energy consumption by stepping up energy productivity.

Key words: *Sustainable energy systems, back-casting-scenarios, German Parliament's Enquete Commission on Sustainable Energy*

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Introduction

A turnaround in energy policy on a global scale is an elementary precondition to sustainable development. Energy wastage in the North and challenging energy shortages in the South are signals of the unsustainable trends in the global energy system. If the current global trends of primary energy consumption and increasing CO_2-emissions are not changed and if the developing countries (DC) try to copy the industrialized countries (IC) and their unsustainable production and use patterns of energy systems, the risks of climate change, of nuclear accidents and of resource wars will increase. Taking the latest Reference Scenario of the International Energy Agency (International Energy Agency, 2004) as an example and as an indicator for possible developments of the world energy system, the perspectives would be frightening: If current policies were not changed, the world's energy demand in 2030 would be 60% higher and the CO_2 emissions would increase by even more than 60%. Though a cumulative amount of $ 16 trillion would have been invested between 2003 and 2030, the number of people without electricity will fall only slightly (from 1.5 bn to 1.4 bn) and those using only biomass for cooking and heating in unsustainable ways will even grow from 2.4 bn to over 2.6 bn in 2030. On the other hand, a look into the future based on alternative scenarios and a growing number of good practices in many countries show that this gloomy development does not have to happen. Putting only a recently considered set of new policies into practice, the perspectives could be changed to a "more sustainable" world energy system (e.g. IEA's "World Alternative Policy Scenario"). As other scenarios for the world energy system show (see below), this "Alternative Policy Scenario" of the IEA does not include all cost effective potentials offered by a more efficient use of energy and by the huge potentials and learning effects of decentralized technologies based on renewable energies and co-/trigeneration (WEC, 1998). Mankind is at the crossroads: Within the next 10 years it has to be decided whether we want to rely on the current risky and unsustainable patterns of energy use. Or if we decide to switch to sustainable energy paths, giving first priority to energy end use and supply efficiency and fostering the market introduction of a broad mix of renewable energies. Sustainable energy paths should be based on the following principles:

- Access to energy services and fair shares for all, including fair partnerships with developing countries

- Effective conservation of resources and protection of environment, climate and health
- Social acceptability now and in accordance with the needs of later generations
- Low risks, fault tolerance and contribution to mitigate international conflicts
- Cost-effectiveness including external costs

Based on the principle of common, but differentiated responsibilities, industrialized countries (IC) should take the lead in climate mitigation: To reduce the global CO_2-emissions by about 50% up to 2050 according to the UNFCC, an even more ambitious reduction target of 80% for IC seems to be necessary in the long run. These targets are in line with a „tolerable window" of climate change: The rate of temperature change should not be more than 0,2 ^{o}C/decade; the mean global temperature increase should not be more than 2 ^{o}C and CO_2-concentration should stay below 450ppm (WBGU, 2003)

Enhancing energy productivity: The key to sustainable development

The recent scenarios of the IEA are only one example out of many others. More than 400 long-term global energy scenarios (2050/2100) have been charted out. They differ greatly in terms of methodology (e.g. forecasts, projections, scenarios), technology mix, economic and population growth, as well as CO_2-emissions. What are their messages for decision-makers: Everything is possible in an uncertain future? Wait and see, let the markets find the right solutions? Should we rely on the conventional wisdom of recent energy policies and a "laissez-faire" style of politics? The answer is no, because "business as usual" (BAU) would be a disaster. The purpose of scenarios and the strategies change when we ask "How do we want to live in future and how do we get to agreed societal goals?" founding new politics on a "back-casting" scenario analysis and cost-effective energy services. As an example: As soon as societal goals for climate protection have been decided by parliament (e.g. a reduction of CO_2 by 40% up to 2020 in OECD countries) "back-casting"-scenarios could help to answer the question whether and how this goal can be reached in a cost effective way (Bleischwitz and Hennicke, 2004).

Of course, with this methodology we cannot avoid future uncertainties and surprises, but we can change known unsustainable trends now and base our long-term decisions on precautionary and safety principles. In short: it should be tried to decouple the increase of living standards and energy services as much as possible from the use of non renewable and risky energy supply (Miketa, *et al*., 2002). This could be done by a global convergence strategy: Cut per-capita energy consumption in IC (at least by half) through more efficient use of energy without decreasing living standards. Keep the necessary development-related increase of per capita energy consumption in DC as low as possible from the very outset by deploying state-of-the-art energy conversion technology, while standards of living can grow rapidly. How is that possible?

More wealth with less energy consumption: A global "Factor Four"-scenario

What would the world of energy look like in 50 years if all efforts were based upon maximised end-use efficiency and the consumer needs (in all sectors including industry and transportation) for cost-effective, risk-minimising energy services? The user seeks the utility derived from energy (e.g. warm housing, electric power, mobility), the kilowatt hours of final energy are merely the means to these ends. The ultimate economic goal of energy use is not cheap and risky kilowatt hours, which can be expensive when external costs are added. Instead, the economic rationale of sustainable energy systems aims to deliver least cost energy services, which are calculated on a life cycle cost base (including a pragmatically calculated adder for external costs) plus the incremental costs of efficient conversion technologies.

This concept of least cost energy services is closely connected to the "Factor Four" formula and the report to the Club of Rome (Weizsaecker, *et al*., 1998). The "Factor Four"-Scenario produced by the Wuppertal Institute (Lovins and Hennicke, 1999 and Lovins, *et al*., 2004) has taken up the basic ideas of the Weizsaecker-Lovins report and investigated whether the subtitle of the book – "Doubling Wealth, Halving Resource Use"–could be taken as the guiding concept for a worldwide energy strategy. The "Factor Four"-scenario is based on the assumptions of the WEC-scenarios (Nakicenovic and Riahi, 2001 and German, 2002) concerning the main drivers (GDP and world population growth) and regional differentiation. The overall message coming out of this complex modelling analyses is the following: Up to 2050 a factor of three in efficiency improvement is possible and would suffice, in combination with vigorous market introduction of renewables, to pave the way for a sustainable world energy system (50% CO_2-reduction; necessary increase of living standards; gradually phasing out

Table 1: Comparison of the "Factor Four"-Scenario and WEC-C1 Scenario ("ecologically driven")

	1995/97	2020		2050	
		C1	Factor 4	C1	Factor 4
Population (bn)	5.56	7.92	7.58	10.06	9.50
GDP (mer), 1,000 bn US $ [1990]	23.3	40.4		75.0	
Primary Energy (Gtoe/a)	9.5	11.4	9.9	14.3	10.3
Renewables (Gtoe/a)	1.8		2.6	5.7	6.3
CO_2 Emissions (Gt/a)	5.9		5.6	5.3	3.0
Nuclear Energy (GW)	368.0			279.0	0
Energy intensity (PE/GDP % p.a.; Gtoe/bn US $ [1990]; historical average = 1% p.a.)		-1.44%	-2.00%	-1.30%	-1.90%

nuclear). The doubling of the historical rate of efficiency increase (from 1% to 2% p.a.) and a 60% share of renewables in 2050 are feasible and may be sufficient for a risk minimisation strategy up to 2050 (Table 1).

The "Factor Four"-scenario takes into consideration only those efficiency technologies that are already known – at least as prototypes – and assumes their stepped-up market dissemination, especially in the South, within the next 50 years. A high degree of market penetration and substantially reduced costs (e.g. learning curve effects) are probable within the next 50 years for these key technologies like efficient production processes, co- and trigeneration, "passive houses" (30kWh/sqm/a) and "plus-energy houses", high-efficiency household appliances, efficient lighting (e.g. LED) and system-optimised electric drive systems, mobile and stationary applications of fuel cells, super-light and energy-saving vehicles. Additionally system optimisation across the entire process chains (thanks to integrated planning including energy and material) holds out the prospect of huge energy and cost savings. A comparable CO_2-reduction scenario (e.g. keeping climate change within the "tolerable window", assuming an energy efficiency increase of 1.6%/yr, an ambitious supply from solar energy, the sequestration in oil/gas-fields, the phase out of nuclear energy up to 2050) has been conducted by the German Advisory Council on Global Change (WBGU, 2003 and Hennicke, 2004b) based on the A1T-scenario of the IPCC (IPCC, 1995). In Figure 1 the long-term development of primary energy consumption in the "Factor Four-" Scenario is compared to the A1T-scenario of the WBGU as an illustration how a sustainable energy system based almost completely on renewable energies could look like in the long-term.

Both scenarios keep CO_2-concentration below 450ppm. The long-term potentials of increased energy savings and efficiency are comparable in both scenarios. But assuming different rates of economic growth (the main driver of primary energy consumption in a "Business as usual" case), the policies to bring renewable energies into the market and to foster efficiency increase may differ much. In the WBGU-scenario, sequestration options are needed as a bridge to the "solar age" if the rate of energy efficiency increase is not high enough (Hennicke and Fischedick, 2005). How to make it happen? Possible strategic potentials and lessons learned

The IEA's World Alternative Energy Policy Scenario is based on a selected set of additional policies " that countries are currently considering or might reasonably be expected to adopt, taking into account the technical and cost factors, the political context and market barriers". But these only moderate changes in policies "...do not fully reflect the ultimate technical or economic potential. Even bigger reductions of CO_2 are possible, but they would require policy efforts that go beyond what governments are currently considering. The policy measures analysed have not been selected strictly according to their economic cost-effectiveness but rather to reflect the current energy-policy debate" Therefore, it is plausible that within future decades, there will be learning effects for energy-policies as well, especially when public pressure on politics will probably increase with growing damages of climate change (Hennicke and Seifried, 2001). This leaves room for manoeuvre and for a whole set of new policies to implement more ambitious climate protection goals. The decision processes of policy and the private sector could be prepared and rationalized by "Back Casting"-scenarios. Public involvement by stakeholder dialogues and transparency still support the implementation process. It has been underlined that "Back-Casting-"scenarios are only sophisticated mind maps for

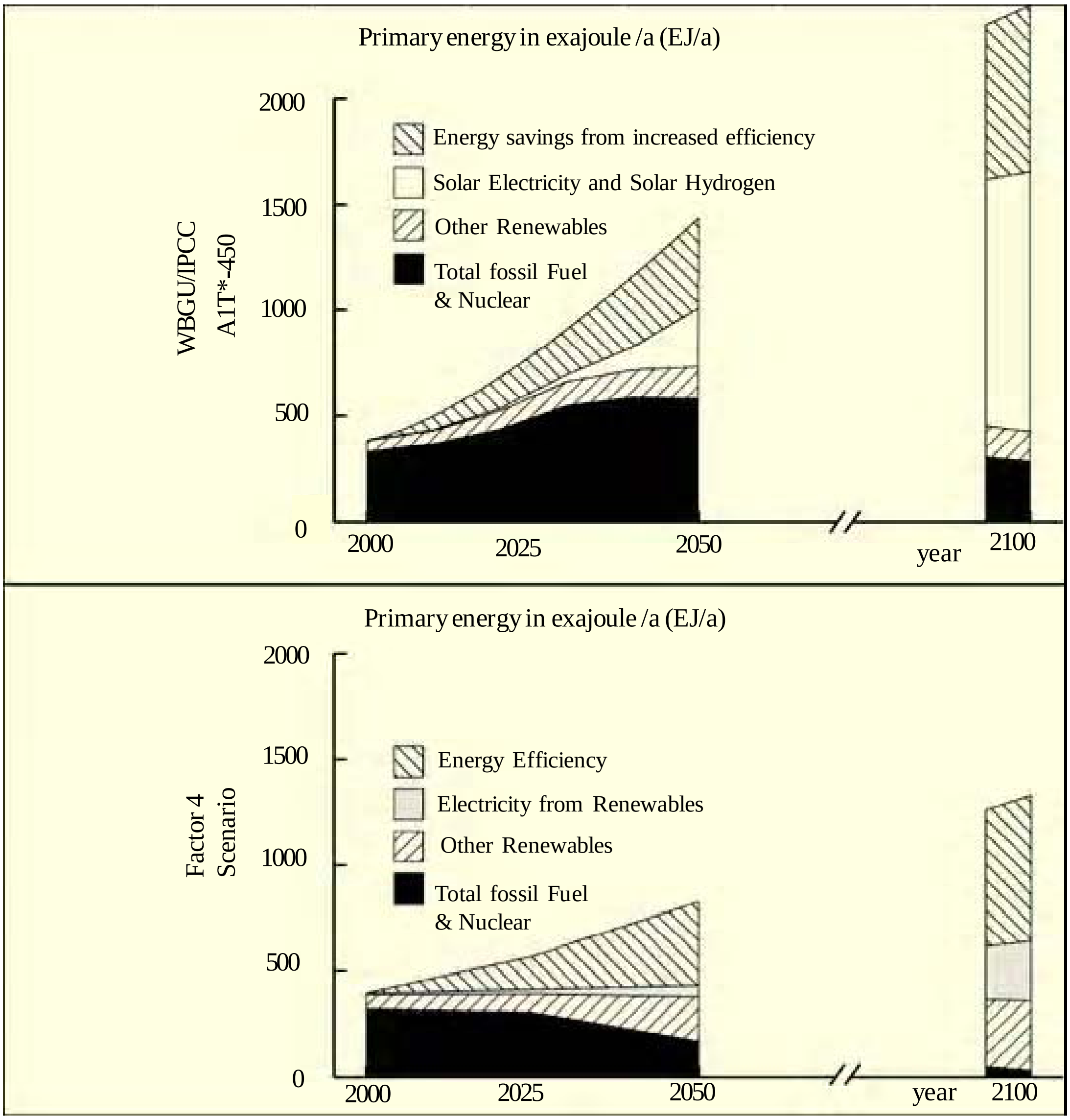

Figure 1: Comparing the contribution of efficiency and solar energy in two long-term word energy scenarios of sustainable energy systems

better decision-making, but no forecasts. To demonstrate and convince politicians, managers and citizens how ambitious goals and structural changes for sustainable energy systems could be realised, it seems to be necessary to look into strategic potentials and lessons learned from international experiences and "good policies". It is possible to foster social learning and the dissemination of "good policies"; of course, successful laws and regulation from other countries must be adapted to the specific national conditions (Hennicke, 2001).

In addition to technology and know-how transfer, increased knowledge about successful instruments to overcome barriers and market failures could help to accelerate the market introduction of efficiency and renewables. To be brief, we pick up only some selected data and indicators. Ambitious quantitative targets for efficiency, renewables and cogeneration (see below the recommendations of the German WBGU) are necessary to foster the market introduction and to realize the potentials for cost degression and learning effects.

What are strategic options and potentials for sustainable energy systems?

- Foster dissemination and use the benefits of technological leap frogging:

- Using technology and know-how transfer: We can take *total energy intensities* (PE/BIP1996) as rough indicators of the potential for technological leap frogging; these intensities differ by the following factors compared to Japan: Europe (2x): USA (3x): China (11x) : Russia (18x)

- Fostering market introduction of *co- and trigeneration*: Combined heat/cold and power production for industrial processes and for district heating/cold systems is a very attractive option to increase efficiency and to decrease costs for power and heat/cold production. The main reason for the great differences *in market shares* of electricity from CHP is the missing of incentive schemes, only some are connected with climate conditions: >35% (NL, DK, FL); about 10% (GER, China); about 5% and less (US, Japan, Brazil, France, India). Recommendation of the German WBGU: Raise the CHP-share up to 20% in all OECD-countries by 2020.

- Sustained markets for electricity from renewables and learning effects can be realized

- Establish incentive schemes for renewables: Global potentials for renewable electricity production are huge and diversified: The potential of 141,400 TWh compares to the total electricity production in 2000 of 15,400 TWh e.g. 34% energy corps; 25% solar; 13% wind; 10% hydro; 9% biomass; 9% geothermal. Recommendation of the German WBGU: raise the share of renewables in electricity up to 25% (2020) and up to 50% (2050)

- There are many possible incentive schemes (e.g. tradable quota, tax credits etc.). An international comparison shows that the motivation of investors is closely related to stable market conditions and fixed renumerations. In Germany, a dynamic market development for renewable electricity could be created by guaranteed feed-in tariffs; with the support of the Renewable Resource Act, the installed German wind power capacity has increased by 14 GW in 10 years, reducing costs/kW by a factor of 3.5

- Encourage innovations and R&D on Renewables, Distributed Power Systems and energy material efficient techniques

- There are interesting technological convergence trends in IC and DC concerning decentralized systems solutions. An assessment of the possible “Top Ten” for German R&D-policies had the following result (Wuppertal Institute, 2004a and 2004) Supply side: Clean Coal, Decentralized CHP/Micro Turbines/ Fuel Cells, Solar Thermal, PV/building integrated, Biomass gasification, Geothermal/Hot dry Rock b) Demand side: LED, Small electric motors c) systems solutions: Micro grids, alternative fuels/ biofuels/BTL/H2, sustainable office buildings, “passive” and “active solar” buildings; alternative propulsion systems/hybrids/mobile fuel cells, optimised ultra-light vehicles. Most of these key technologies for a highly industrialized country like Germany can be adapted to DC conditions as well.

- Learn from best practice to overcome barriers in the field of end use energy efficiency

- On a global scale, there do exist a lot of experiences on policies and measures for fostering energy efficiency. The main lessons learned are: a) that the markets for energy services need regulation; otherwise market failures and barriers could not be overcome and b) that a policy mixes (a bundle of instruments) and specific incentive schemes are needed to foster the market introduction of efficiency technologies (Wuppertal Institute, 2001).

- Avoid lost opportunities by fostering efficiency in DC: Because of the high growth rates in many developing countries, the energy efficiency potential of advanced technologies compared to the reference case e.g. in new buildings, vehicles, production processes, appliances etc. is much higher than in saturated rich countries.

Encourage the integration of efficiency and renewables on a strategic and project level; every project for renewables should have an efficiency component, (compare GTZ/Wuppertal Institute 2004)

- Establish targets and standards to reduce energy consumption (e.g. the Japanese “Top Runner Program”)
- Reduce energy consumption by voluntary agreements in energy intensive industries (e.g. 20% in NL)
- Increase car fleet efficiency with standards (e.g. Californian CAFE-standards in 10 years by a factor 1.75)
- Use national and business internal emissions trading schemes: e.g. BP‘s and Shell‘s internal ET has generated net profits from reduced energy use
- Implement DSM-programs; establish competition neutral energy efficiency funds (e.g. in the US and in Europe)
- Lower average heat consumption (kWh/sqm/a) by building codes; e.g. the heat consumption in typical German state of the art buildings was reduced by a factor 13 (from 400 to 30 kWh/sqm/ a) within 25 years
- Create Energy Service Companies (e.g. more than 600 ESCOs in Germany realize profitablecontracting projects with SMEs; saved energy between 20-40%).

- Raise resource productivity ("eco-efficiency") by encouraging integrated energy and material efficiency projects
- Integrated policies to reduce energy and material consumption (raise resource productivity) are missing in many countries. Therefore the synergies for cost reduction and environmental protection through optimized design, new production processes with minimized residues and more sustainable consumption patterns are often neglected. For example up to 5% of German primary energy could be conserved additionally by efficient material management (e.g. recycling)
- In Germany a national "Impulse Programme Material Productivity" is in preparation; as has been shown by macro-economic I/O-analyses this programme could create up to 800,000 new jobs, cut public budgets and would help to find new business fields
- Safeguard access to advanced energy for the poor (2.4 billion people)
- On a global scale, the access to advanced energy for all people is a fundamental prerequisite for sustainable development. Many promising policies and measures exist e.g:
- Establish public-private partnerships and integrate rural electrification programs for income generation into ODA to eradicate energy poverty in developing countries
- Establish micro credit programs (like Grameen Shakti; Solar Home Systems)
- Build a network of decentralized international "Efficiency and Renewables Centers" as a follow up activity of the Renewables 2004
- Found a "Knowledge Diffusion Network" (Centre) in cooperation with the M&E departments of the "GEF-family" (to disseminate lessons learned from efficiency and renewables projects and from "good politics" for market aggregation);

Case studies for Germany: Sustainable energy systems can be financed

It was refered to recent long term scenario analyses of sustainable energy systems which have been conducted on behalf of the German parliament's Enquete Commission on Sustainable Energy (German Bundestag, 2002) and some follow up scenarios (called "expansion scenarios") conducted for the German Ministry for the Environment (Nitsch, *et al.*, 2004). Major scenario results are:

- Sustainable energy systems presuppose advanced efficiency

From a technological and economic point of view, far-reaching efficiency improvements are possible. This has been proven by comprehensive analysis for the building and transportation sector and for electrical devices (e.g. appliances, motor drives, ventilation, pressurized air, lighting) and for integrated strategies to reduce material and energy consumption. The annual efficiency improvements introduced to the "expansion scenarios", expressed as annual averages for the period 2000 – 2050, are 2.6%/a for primary energy consumption (which almost doubles the long term historical trend) and 1.8%/a for electricity consumption, an increase of 50% compared to the historical trends (Figure 2, lower lines). The implementation of the efficiency strategy means that about one third of present-day primary energy consumption will not be needed in 2050 (Figure 3) even though real GDP is still growing by an average rate of 1,4% p.a.

The resulting reduction in CO_2-emissions by 2050 is about 280 million t/yr, contributing with a share of about 55% to the necessary reduction of 509 million t/yr (compared to the reference case). Thus an effective efficiency strategy is indispensable if the reduction target for 2050 (80% CO_2-reduction compared to 831 million t/yr in 2000) is achieved on time and in an economically acceptable way.

In the "expansion scenarios", the future development of the transport sector is characterized by efficiency improvements for all means of transport (e.g. private cars, trucks, buses, trains, aeroplanes), supplemented by shifts of traffic volume from the roads to other environmentally more benign means of transport. This makes it possible to halve the fuel consumption by 2050 comparing to the reference scenario (Wuppertal Institute, 2000b). Further more an ambitious expansion of renewable energies (with a share of only 0.9% currently) in the transport sector seems to be possible, but the ecological and economic restrictions should be recognized. A strategy that attempts to replace fossil fuels without making substantial changes in mobility structures and vehicle-specific energy expenditure will have no chance of being successful (Figure 4).

Decentralized electricity supply - cogeneration is one strategy pillar

The electricity supply sector in the „expansion scenario"provides for a total of 80 GW of new power plants by 2020, 45 GW coming from renewable energy sources. The resulting power plant park will generate 504 TWh/yr of electricity, which is more

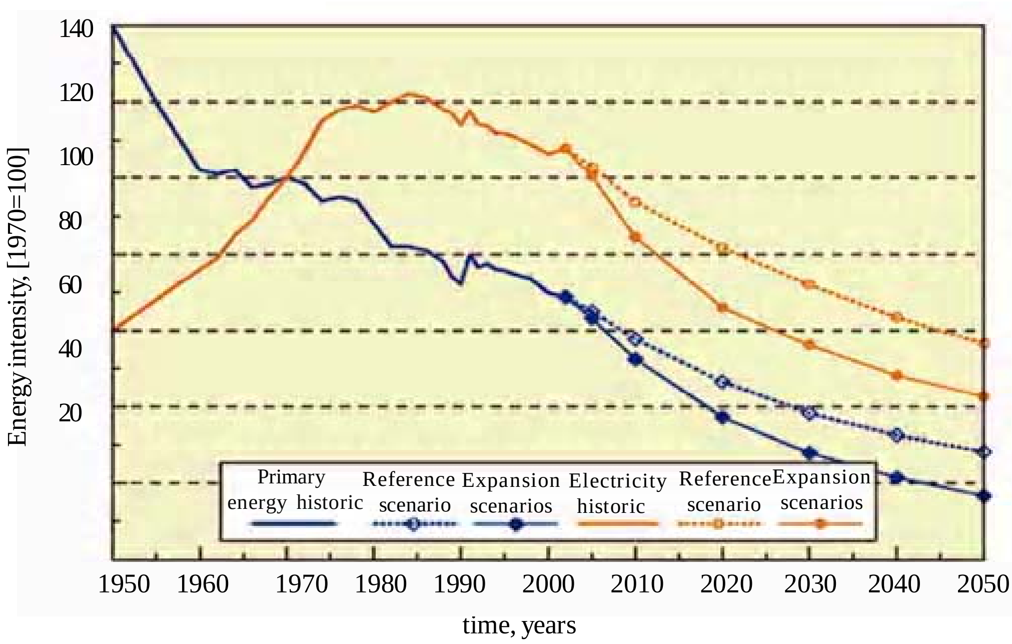

Figure 2: Energy intensity (primary energy consumption/GDP; electricity/GDP) in the reference and "expansion scenarios" (primary energy consumption/GDP (1970) = 9.93 GJ/1000 €$_{2000}$; electricity/GDP (1970) = 0.787 GJ/1000 €$_{2000}$; figures for 1970 = 100)

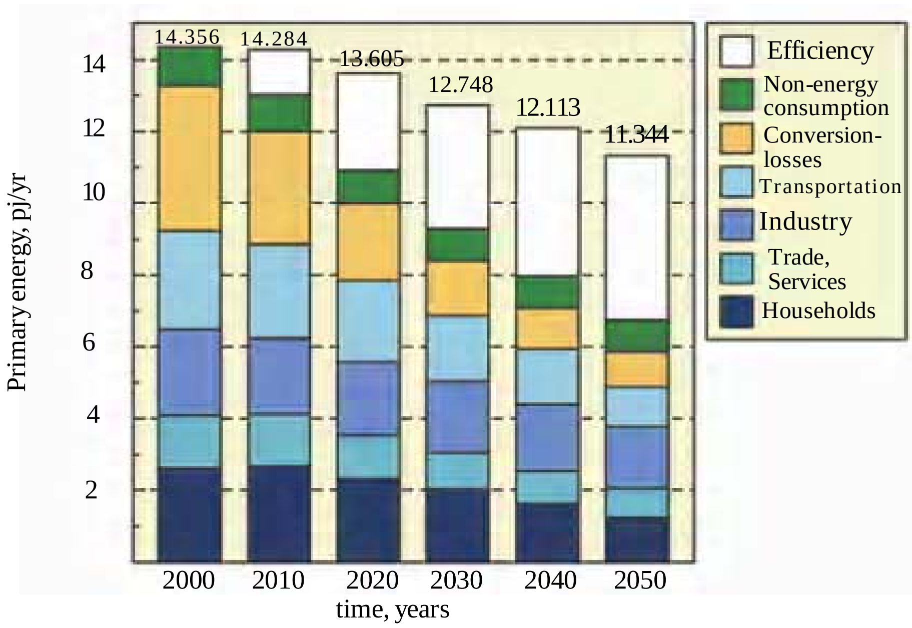

Figure 3: Final energy demand and the resulting primary energy in the "expansion scenarios". "Efficiency" = additional reduction compared to reference scenario achieved by more efficient end use and production (e.g. cogeneration) of energy

than some decades before and caused by a rising hydrogen production share. The proportion due to renewable energy systems is 68% (Figure 5), and the share of electricity from CHP is around 40% in 2050. In the scenario 65 TWh/yr (about 20%), of the total of 340 TWh/yr from renewables in 2050 is provided via a new European electricity network from North European and North African sources (e.g. solar thermal, off shore wind power, hydro power). This offers benefits for both the supplier countries (e.g. countries in North Africa) and the importing countries.

Compared with the reference case in which 65% of the additional capacity required by 2020, or some 45 GW, is produced by condensing and CHP power plants, the structure of electricity supply has to be changed in a systematic way: In a sustainable electricity sector up to 2020, roughly a quarter of electricity requirements should be (a) avoided by improving end use efficiency, (b) produced by distributed co-generation, (c) produced by renewable energy systems and (d) produced in large-scale condensing and CHP power plants.

• Efficiency improvements can "buy down the costs" of renewable electricity supply Speeding up improvements in efficiency is favourable from an economic point of view, since in many cases – calculated on a life cycle basis – saving energy is more cost-effective than producing additional energy. Some of the savings potentials are cost effective within short amortization periods, which results in direct cost savings if the construction of new en-

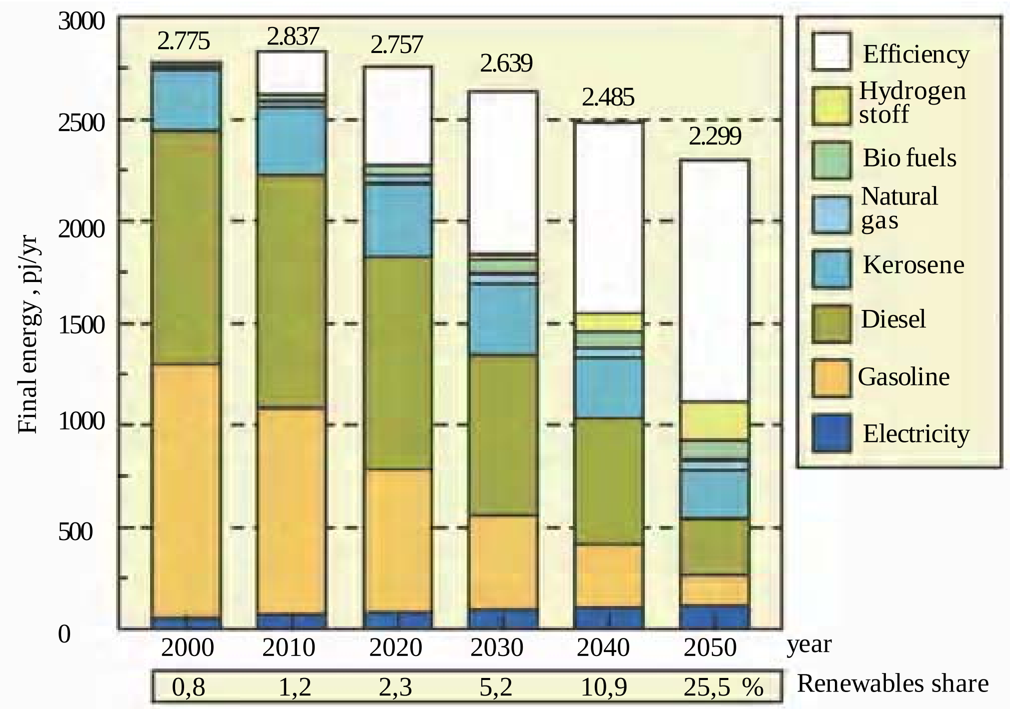

Figure 4: Structural changes in renewable fuel supply shares in the "expansion scenario" in the transport sector.

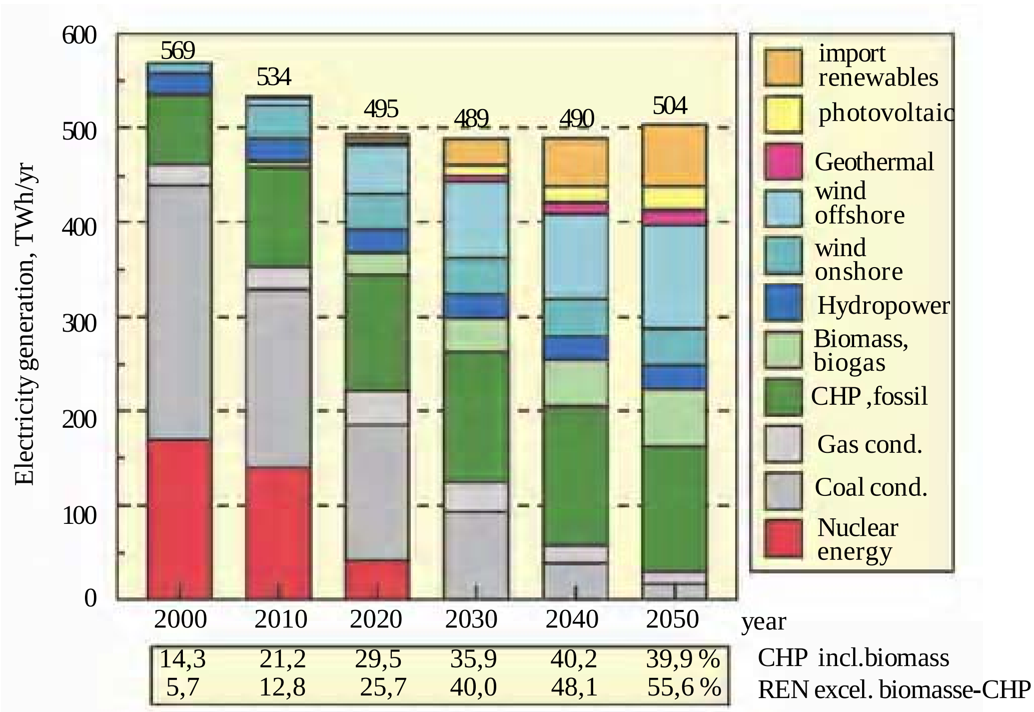

Figure 5: Power generation by power plant types and energy sources in the „expansion scenario". The increase from 2030 onwards is due to the provision of electricity for hydrogen production (2030 = 10 TWh/a, 2040 = 33.5 TWh/a and 2050 = 70 TWh/a)

ergy production installations can be avoided. The "expansion scenarios" show negative differential costs starting in 2030, or at the latest 2040; in other words, after 2030 the total system costs for energy will be cheaper than an energy supply system that continues to be based on fossil energy sources. This has especially been shown for the electricity sector. The same holds true for the building sector, where active solar measures usually do not make sense until measures have been taken to improve the energy efficiency of buildings. Thus, a strategy of increased energy efficiency has the macro-economic effect of compensating the additional costs for the forced market introduction of renewable energies. For this reason, especially in the period 2000 – 2020, when the absolute differential costs of expanding renewables will be the greatest, highest priority should be given to a strategic initiative to raise energy efficiency e.g. by using Demand Side Management, Third Party Financing, Energy Saving Funds, Labelling and others (Hennicke, 2004).

The costs of electricity production in Germany currently stand at an average of 3.85 Euro cents/kWh, because many power plants are depreciated; it will increase as a result of investments into new power plants and higher fuel prices. In the "expansion scenario" a steady reduction of CO_2 emissions from the present 335 million t/yr to 75 million t/yr in 2050 as a result of an electricity mix of highly efficient CHP -plants, distributed micro CHP plants and fuel cells and a marked increase in the share of renewables is assumed. This provides an appropriate basis to compare future electricity prices in line with a risk-minimising energy policy objective. In 2050, the "expansion scenarios" (strongly utilizing CHP, renewable energies and energy efficiency), depending on the assumptions about fuel price increases, fulfil this objective with average electricity production costs in the range of 6.2 Euro cents/kWh. In the reference case a comparable climate protection requirement can only be met with CO_2-sequestration technologies (assumed from 2020 onward). Assuming that this technology can be used, this leads to average electricity production costs in 2050 of around 8.5 Euro cents/kWh. Thus an energy supply system that continues to rely on fossil fuels is considerably more expensive than steering a new course towards efficiency improvements and renewable energy sources.

- A target and technology specific policy mix is needed to foster efficiency

The German Enquete-Commissionon on Sustainable Energy recommended detailed strategies and instruments to implement the above analysed ambitious sustainable energy system (compare Energy Policy, 2004)

. The implementation process requires public support, incentive schemes, new organisations and guidelines especially for a policy focussing on efficient energy use. Figure 6 summarizes the policy mix proposed by the Enquete Commission.

Summarizing the major findings of several long-term sustainability scenarios for Germany, one can conclude:

- A sustainable energy system is technically and economically feasible; many uncertainties exist, but a robust technological corridor (end use efficiency, CHP, renewable) should be used anyhow
- There are moderate differential costs of a sustainable energy strategy compared to the business-as-usual case; positive employment effects and export advantages in growing world markets for renewables and efficiency equipment will be the benefits.
- A substantial increase in the conversion and utilization efficiency of all energy sources is needed (e.g. factor of 3 to 4 up to 2050).
- Advanced efficiency improvements make it easier to finance and foster the market introduction of renewables.
- Within the next decades, a structural change of the power plant sector (e.g. decentralisation, diversification, participation) has to be managed.
- There is a need to speed up the market introduction of renewables: Timely integration into a supra-regional and trans-European system for importing electricity form renewable sources (e.g. solar thermal power plants in North Africa) is needed.
- It doesn't make sense to overspeed "hydrogen strategies from renewables" before 2030. There are cost effective alternatives which can pave the way to a "hydrogen economy" in the long run (2030 and beyond)
- A new policy mix of instruments is needed: Global, sector and technology specific instruments are necessary to overcome barriers and to combine the benefits of cost reduction from efficiency with cost degression effects of renewables (e.g. learning curves).

By stepping up energy and material productivity, (qualitative) economic growth can be decoupled from absolute levels of non-renewable energy consumption. This eco-efficiency revolution should be accompanied by a discourse on more environmentally viable lifestyles and on new patterns

Targets up to 2020:

1. Improve overall energy productivity by at least 3 percent p.a.
2. Increase energy form renewable by a factor of 4 (electricity) and 3.5 (heat); increase electricity from CHP by a factor of 3
3. Reduce average specific heating demand in modernised old buildings to 50 kWh/m2/a (compared to 150kWh/m2/a on average)
4. Reduce car fleet consumption to 3.5. or 4 litres/100km

Instruments:

- Liberalise and re-regulate the power and gas markets in a climate sound way
- Establish an energy efficiency fund (financed by non by-passable fee on tariffs; modelled on Danish and British experiences; activities: conduct procurement auctions; support and evaluate DSM-programs; tendering procedures for energy-saving services; initiate R&D activities for efficiency technologies etc.)
- Eliminate subsidies for energy sources which are harmful to the climate or holding high risk potential (coal, nuclear energy)
- Push ahead with environmental tax reform
- Implement a national “impulse programme” promoting efficient electricity consumption
- Establish a national carbon fund for project-based CDM and JI activities (using tradable permits to transfer technologies to developing countries)
- Support local/municipal climate-protecting activities
- Reinforce electricity feed-in law for renewable energy
- Introduce mandatory labelling for electric power from different sources
- Promote labelling and standards in electricity services

Figure 6: National targets and instruments for climate protection and energy efficiency policies highlighted by the German Enquete Commission on Sustainable Energy

of sustainable consumption and production. In a global sense, gaining time may be the most important goal of all.

References

Bleischwitz, R. and P. Hennicke, Eco-efficiency, regulation, and sustainable business: towards a governance structure for sustainable development. Edward Elgar Publishing Ltd., Cheltenham, 2004

German, B., Enquete Commission of the 12th. German Bundestag on Protecting the Earth´s Atmosphere. A better Future for the Earth: Sustainable Energy Policy for lasting Climate Protection. (In German language). BT 12/8600, Bonn, 1994

German B., Enquete Commission on Sustainable Energy Supply. Final Report. BT 14/9400, Berlin, 2002

GTZ 2004/Wuppertal Institute, Towards Sustainable Energy Systems: Integrating renewable energy and energy efficiency is the key, discussion paper for the International Conference “Renewables 2004”, Wuppertal / Eschborn, 2004

Hennicke, P., The Economics of Climate Protection. In: International Review for Environmental Strategies, ***2*** *(1): 9-36, 2001*

*Hennicke, P., Scenarios for a robust policy mix: the final report of the German study commission on sustainable energy supply. In: Energy Policy,****32*** *(15): 1673-1678, 2004a*

Hennicke, P., Strategies for sustainable energy systems and for climate change. In: Bleischwitz, R. / Kanda, Y. (ed.), Governance of Markets for Sustainablitiy, Jdzb documentations, ***6****, 2004*

Hennicke, P. and M. Fischedick, Towards sustainable energy systems: The related role of hydrogen, forthcoming, 2005

Hennicke, P. and D. S. Negawatt, Fountainhead, Printed in Japanese language, 2001

International Energy Agency, World Energy Outlook, Paris, 2004

IPCC, Intergovernmental Panel on Climate Change, Working Group III. Summary for Policymakers: Economic and Social Dimensions of Climate Change. Montreal, 1995

Lovins, A. and P. Hennicke, Voller Energie. Vision: Die globale Faktor Vier - Strategie für Klimaschutz und Atomausstieg. Buchreihe EXPO 2000, Campus Verlag, Frankfurt a. M., New York, 1999

Lovins, A., D. Kyle, B. Odd-Even, K. Jonathan and G. Nathan, Winnning the Oil Endgame: Innovation for Profits, Jobs, and Security. Snowmass, 2004

Miketa, A., L. Schrattenholzer and K. Riahi, (IIASA). Policy implications from a sustainable global long-term energy scenario. Interim Report for The Fourth International Forum of the Collaboration Projects, Cabinet Office, Government of Japan, 2002

Nakicenovic, N. and K. Riahi, an assessment of technological change across selected energy scenarios. IIASA, Laxemburg; World Energy Council WEC, London, 2001

Nitsch, J., Ecologically optimized expansion of renewable energy utilization in Germany. Study conducted for the German Ministry for the Environment, Berlin, 2004

WBGU, German Advisory Council on Global Change. World in Transition: Towards Sustainable Energy Systems, Summary for Policy Makers, Berlin, 2003

Weizsaecker, E., A. Lovins and H. Lovins, Factor four, doubling wealth - halving resource use. Earthscan, London, 1998

World Energy Council, World Energy Council / Institute for Applied Systems Analysis IIASA. Global Energy Perspectives to 2050 and Beyond. London/Laxemburg, 1998

Wuppertal Institute et al. IRP in a Changing Market. Completing the market for Least-Cost Energy Services, Strengthening Energy efficiency in the Changing European Electricity and Gas Markets. Commission, Wuppertal, 2000a

Wuppertal Institute. Collaboration Project on Studying Economic and Social Systems in the 21st. Century, Conceptual Framework and Proposal. Unpublished paper, Wuppertal, 2000b

Wuppertal Institute, Application of European-Based Policies on Resource Flows and Energy to Japanese Sustainable Development Policies. Unpublished paper, Wuppertal, 2001

Wuppertal Institute, Der Beitrag regenerativer Energien und rationeller Energienutzung zur wirtschaftlichen Entwicklung in Nordrhein-Westfalen, Studie für das Ministerium für Energie, Verkehr, Landesplanung NRW, Endbericht, Wuppertal, 2004