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Decoupling Well-being from GDP – Towards a New Kind of Technological Progress

1. Basic challenges and concepts

Humankind is approaching a critical turning point in its history. Most important is the well-being of a growing population in developing countries, and sustainable development is one of its preconditions. Sustainability implies many aspects: beyond the physical aspects of resources and global ecological health, it is in particular a phenomenon of social cohesion, economic driving forces and of the differentiation between cultures.[1] Here an integrated perspective is necessary to analyse the challenges, risks and opportunities facing societies to overcome present limitations. Some of the challenges and unsolved questions are:

- **Conflicts between quantitative economic growth and sustainability**

Sustainability is not possible without economic growth. Economic growth following past and present patterns, however, has increased environmental pressures.[2] Therefore, without a radical structural change in the patterns of growth ("qualitative growth", e.g. dematerialisation; service orientation; closed loop economies; up cycling; zero emissions), mankind seems to be captured in a deadlock: If societies succeed in accelerating traditional quantitative economic growth and if the growing population in the South tries to copy the per capita resource consumption of the North, then further deterioration of nature would seem to be inevitable.[3] On the other hand without growth in goods and services, as well as in profits and personal incomes, it will not be possible to increase living standards, to overcome poverty and to reduce unemployment especially in the South.

- **Short-term personal versus long-term societal sustainability**

In most regions of the world there is a pronounced conflict between short-term personal needs – for jobs, income, well-being and physical existence – and long-term sustainability. In Europe millions of jobs are missing and – by following traditional patterns of economic growth and labour policies – sufficient economic growth to reach full employment in Europe cannot be expected. Moreover, an accelerated economic development is necessary in most developing countries to overcome hunger and poverty. This situation generates a high priority for jobs and economic development. These conflicts can only be resolved by long-lasting social learning processes and by the willingness to support an economic development compatible with longer-term environmental necessities ("qualitative growth"[4]). Questions of international and intergenerational equity and justice are involved.

- **Regional differentiation**

Diversity is a necessity for ecological, social, economic and cultural sustainability as well as for the regional well-being of people and for regional sustainability. The huge variations in culture and ecological conditions are a source of regional differentiation. With differentiation regional economic imbalances as well as national and ethnical movements occur. This aspect deserves careful political analysis of how to deal with regional imbalances – which ones to preserve and which ones to fight.

- **Globalisation**

Globalisation is often perceived as being only an economic factor but it is not only a matter of trade. Globalisation also concerns people, knowledge, travel, culture and learning. Globalisation occurs through rapidly increasing interconnectivity of the globe. Globalisation is the precondition of exchange and interconnections of all kinds as it allows travel and tourism, removes barriers to trade and the exchange of information, and as it supports learning about and from each other. Globalisation means both risks and opportunities to many regions. But one key question has still to be resolved: What globalisation will be sustainable and how can we keep globalisation and world markets within the "new limits to growth" (see below)?

1 See IPCC (2001c), especially Banuri&Weyant: Setting the Stage: Climate Change and Sustainable Development
2 See OECD (1998)
3 See for the energy sector my contribution, Lovins / Hennicke (1999), short summary in English: Hennicke (2001)
4 Of course, economic growth is always measured in quantitative terms. "Qualitative growth" in a German discussion context puts the focus on the structural and environmentally benign changes. For example: on the way to sustainable energy systems, the growth in renewables and energy efficiency technologies will be high (e.g. growth in wind power capacity by 37% up to 12000 MW at the beginning of 2003). On the other hand, fossil energy inputs and markets have to be reduced.

- **Information society**

Another major challenge is posed by the driving forces of the information society. It offers vast new possibilities to become sustainable; essentially, neither sustainability nor dematerialisation seems to be possible without the means of an information society. However it increases the destruction rate of jobs in established industries making the more established ones obsolete, and it accelerates the exchange of capital, goods and services as well as the growth of new infrastructures – and therefore poses new threats to sustainability. Without conscious and deliberate actions to advance favourable forms of the information society, this might well worsen the environmental situation and become another burden to building sustainability.[5]

- **Population growth and "ageing societies"**

Worldwide, population growth and rising per capita incomes are still the most important driving forces of increased consumption of natural resources. On the other hand and in the longer run, the inversion of the population pyramid is becoming a worldwide phenomenon in industrialised countries: in most OECD countries the number of older people is increasing and the number of younger ones decreasing. This new mega-trend has paramount ecological, financial and socio-economic implications for sustainable development. For example, it puts strain on public finance, social security and health systems. Moreover, it changes mobility needs and systems, lifestyles as well as the tastes and preferences of customers; for example, long-term "business as usual" energy scenarios for Germany show a decrease in energy consumption mainly caused by reduced population.[6]

Given the range of these new challenges and risks, the old strategy of "modernisation" falls short in shaping a desirable future for humankind. The first reports and forecasts on the state of the environment in the 1970s brought the finiteness of raw materials and above all of fossil fuels into the focus of public interest (Meadows 1972). Though the physical exhaustion of fossil fuels has not turned out to be the most pressing problem, things have even worsened: It is the distribution and relative scarcity of resources which accelerates regional conflicts (e.g. on oil, gas and water) and it is the limited capacity of ecological systems (e.g. the atmosphere) to absorb pollutants and wastes which is threatening to dictate limits to the economy ("Naturschranken"): Not only the earth, the sky is the limit.

Since the end of the 1980s, and since the Earth Summit in Rio de Janeiro in 1992 at the latest, this realisation has crystallised into a new conception of development. "Sustainable development" is the catchphrase used to term a form of development in which the needs of present generations are to be satisfied without compromising the ability of future generations to meet theirs. With this new guiding concept goes the realisation that environmental policy problems cannot be examined in isolation from economic and social (as well as cultural) developments.

If one accepts the preservation of natural resources as a natural precondition to the sustainability of a society, then this defines a framework of possible economic and social options. Within this action space, human beings can exploit the natural environment – with the precondition that the right of every human being to use resources and to pollute the environment must be recognised. Ethically speaking, no human being in the North has "a right to pollute" if the impacts of these aggregated rights deprive the people in the South or further generations of satisfying their needs. To put it into more pragmatic terms: In principle the per capita resource consumption in advanced economies should be reduced to a level which is transferable to a growing world population without destroying nature. Quoting Hans Opschoor,[7] we term this action space the "environmental space" (German: Umweltraum). This environmental space is a function of the carrying capacity of ecosystems, the recuperative power of natural resources and the availability of raw materials. The concept thus recognises the existence of "new limits to growth" ("Naturschranken").[8]

The concept not only embraces the ecological dimension but also that of international and intergenerational equity. Just as future generations should have a right to a natural environment that is as intact as possible, proceeding from the above value decisions, equal opportunities should be given within a generation. The integration of this social aspect lays the foundation for a balancing of interests with the countries of the South.

Accepting the limits of environmental space and the existence of "Naturschranken", we need a new approach in the economic and social as well as in the ecological debate. Until now, environmental policy has largely taken an end-of-pipe approach, focusing on the disposal or prevention of pollutants. Social and economic implications, e.g. the impact on employment and on long-term economics, were often not integrated into ecological systems analysis. Despite the successes of this approach, it has proven to be inadequate and too cost-intensive. And even if it could be completely successful, environmental problems such as urban sprawl, consumption of landscape

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5 Radermacher 2001, e-Living - Digital Europe (2001)

6 See Comission of Inquiry on Sustainable Energy Supply (2002)

7 See Greening the North (1998)z

8 See Hennicke (ed.), Nachhaltigkeit als Geschäftsfeld, 2002

and raw materials, loss of biological diversity, soil erosion, water scarcity and burgeoning mountains of waste would continue to prevail.
In addition to the specific impacts ascribable to individual substances, environmental policy is therefore becoming aware that the very quantities alone of energy used and substances moved as well as increased land use create a problem. Every product and every service is linked throughout its entire life cycle with energy and material throughputs. Large proportions of these are not economically utilised, and are returned unaltered to the natural environment, which must then absorb them. These masses can be characterised as "forgotten megatons" or "ecological rucksacks" (Schmidt-Bleek 1994). Following the precautionary principle their reduction provides a preeminent contribution to risk reduction, to environmental protection and long-term economic sustainability ("eco-efficiency"), and moreover, reduces conventional pollution. Resource utilisation should be oriented to the following guiding principles:

- No more of a renewable resource should be utilised than can regenerate in the same period.
- Only that amount of materials should be released into the environment that can be absorbed there.
- Energy and material throughputs must be cut down to a low-risk level.

Traditional environmental policy focuses on end-of-pipe pollution control. Based on a systems perspective together with the insight into anthropogenic material flows, modern policy concepts should follow a dualistic approach (Figure 1):

- On the output side, the release of pollutants is regulated in order to reduce well-known problems. This strategy is directed to specific substance flows (e.g. lead, cadmium, carbon dioxide, etc.). Derived policies may be generally characterised as re-active.
- On the input side, the resource requirements are going to be diminished in order to lower the impacts of the resource extraction as well as the effects of the subsequent flows. This strategy is directed to general resource flows (primary material, energy and water) and area requirements. Derived policies may be addressed as pro-active.

Both strategies are complementary rather than exclusive. Pollution control alone could not control increasing resource requirements and a shift in environmental problems due to the control of selected substances. A reduction of resource inputs alone may not be sufficient to keep the flows of specific pollutants under critical levels.[9]

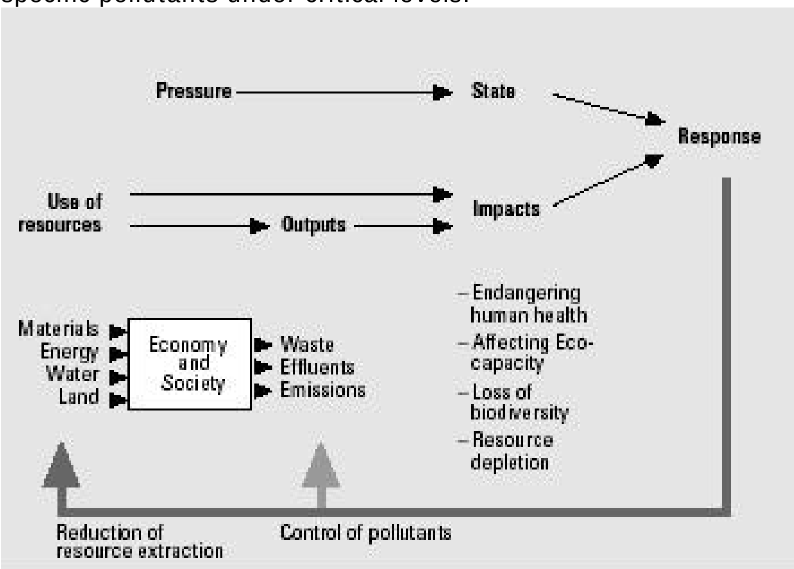

Fig. 1: Physical exchange of anthroposphere and environment (Wuppertal Institute 2000)

Pollution abatement and chemicals control are well-established fields in terms of policy, methods, organisation and technology. However, the reduction of resource inputs is relatively new to the agenda. The increase in resource productivity will guarantee that the economic performance and the welfare produced may be increased while the absolute burden to the environment as a consequence of resource extraction is being reduced.

2. The basic strategy: Decoupling resource use from GDP growth

The challenge of sustainable development requires a comprehensive policy mix serving different ends regarding ecosystems and natural resources' scarcity, distribution of wealth and economic framework conditions. As a necessary but not sufficient condition for an essential leap forward to sustainable development, climatologists recommend a reduction in greenhouse gases (GHG) of some 50% by the middle of the 21st century.[10] However, following a business-as-usual (BAU) strategy, the demand for energy and emissions of CO_2 are likely to double within the next few

9 Bringezu/ Moriguchi (2002).
10 Commission of Inquiry of the 12th German Bundestag on Protecting the Earth´s Atmosphere (1994), IPCC (1995, 2001abc)

decades.[11] Up to now, the Framework Convention on Climate Change (FCCC) and the Kyoto Protocol encourage only marginal GHG reductions in industrialised countries.

An even more depressing picture arises regarding the loss of biological diversity. Although the scientific debate about causes and effects is more complex than in other areas of environmental research, one reason for land conversion and habitat destruction is the gigantic flow of materials harvested and used by modern societies. On average, each inhabitant in the EU, the USA or Japan induces material flows between some 46 (Japan) to 85 (USA, Germany) tons per year.[12] Some scientists claim that protecting the remaining biodiversity will require reducing the current amount of material flows in OECD countries by up to 80-90%.

This issue is further strengthened by the overall concern about increasing waste. Only cautious steps in the direction of a "3R" strategy (reduction, reuse and recycling) have been adopted in industrialised countries; at best, only a relative decoupling of GDP growth and of lead indicators of environmental impacts have been reached in OECD countries (e.g. concerning energy consumption and material flows); in most developing countries material and energy growth still outstrips GDP growth.[13]

Therefore, looking from a global perspective, it has become obvious that any attempt of the developing world to emulate Western styles of mass production and mass consumption would end up in a serious ecological crisis, mainly with regard to the greenhouse effect, the loss of biological diversity and clean water scarcity. There is strong scientific evidence that overuse of natural resources will increase poverty and lead to international security conflicts (e.g. on oil, gas and water). [14]

In fact, in the light of the 11th of September, environmental security must also be ranked among the top policy issues worldwide. Steps in the direction of a more sustainable development are promising contributions to worldwide security politics. After all, per capita energy and material consumption have to be reduced in OECD countries in order to tackle environmental, security and equity questions. Positively speaking, "*resource productivity*" has to be increased drastically (Weizsäcker/Lovins recommended a "Factor Four – Doubling Wealth, Halving Resource Use" 1999; Schmidt-Bleek even speaks of a "Factor Ten", 1994).

As a world strategy even a "Factor Four" increase in resource productivity seems to be an extremely ambitious challenge to technology and civilisation within a time horizon of some decades. But Weizsäcker and Schmidt-Bleek claim that it could happen in the long run, if civil society, business and politicians seriously engage in "greening productivity". But both have not always made it very clear what the factor x idea really means: whether it embraces energy and/or resource flows, whether it is only a normative guideline or a quantitative strategy; and what should be the scope (micro/macro), the intended time horizon and the policy mix to get it implemented. And last but not least, the question of technical "eco-efficiency" (resource productivity increase) has not been integrated into the frame conditions of "sufficiency", e.g. questions of more equal inter and intra-generational distribution of income and wealth as well as of social innovation and lifestyles.

On the programme level and in political declarations, the factor 4 to 10 goal has attracted wide attention. It was adopted by the special session of the United Nations (UNGASS 1997) and the World Business Council for Sustainable Development (WBCSD 1998). The environmental ministers of OECD (1996) expected progress towards this end. Several countries included the aim in political programmes (e.g. Austria, Netherlands, Finland, Sweden; see also Gardener and Sampat 1998). In Scandinavian countries research was launched to test the broad scale feasibility of factor 4/10 (Nordic Council of Ministers 1999). The German Sustainability Strategy aims at a factor 2 increase in productivity of non-renewable raw materials (1994 to 2020), as well as of energy (1990 to 2020) (Bundesregierung 2002). In the European Union, the 6th Environmental Action Plan focuses on the increase of resource efficiency, prevention of waste and sustainable resource management as one of four priority issues (European Commission 2001).

Weizsäcker/Lovins have demonstrated with 50 examples how the Factor Four idea works for specific products and processes.[15] But up to now the "feasibility" of the Factor Four concept on a macro-systems level has only been shown for energy. Two "feasibility studies" of the Wuppertal Institute – showing in quantitative scenario terms how the factor x idea could serve as a guideline for concrete national and international strategies – have been summarised below:

Case study I: A sustainable worldwide energy system

Concerning the energy sector, a technically and economically feasible sustainable world energy strategy has been demonstrated by the "Factor Four" scenario of the Wuppertal Institute.[16]

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[11] (Nakicenovic/Riahi (2001), Miketa/Schrattenholzer/Riahi (IIASA, 2002)

[12] See Adriaanse/Bringezu (1998)

[13] See OECD (1998)

[14] European Commission (2001)

[15] See v.Weizsäcker/ Lovins/ Lovins (1998)

[16] See Lovins/ Hennicke(1999)

Essential assumptions and results are summarised and compared with the "ecologically driven" C1 scenario of the World Energy Council (WEC) in Fig. 2.

Fig. 2: 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%

Source: Lovins, A./ Hennicke, P., Frankfurt/New York 1999; World Energy Council (WEC)

The Wuppertal scenario is a technology oriented "bottom-up" approach with a special focus on the demand side and on end-use energy efficiency. Up to now, a worldwide scenario describing final energy consumption on the basis of the concept "energy services" (e.g. pleasant room temperature, clean dishes, mobility) has not existed. But this approach is necessary in order to assess the technological and socio-economic implications of a "Factor Four" strategy. The Wuppertal scenario explicitly takes into account such highly efficient end-use technologies like "hypercars" (Amory Lovins), "passive houses" (Wolfgang Feist), energy-efficient production processes, efficient lighting and electrical motor drives as well as a large number of efficient appliances, and discusses the impacts of such strategy elements on the structural changes of the energy supply and industrial sectors. The focus is on accelerating the market diffusion, especially in the South, of these "high-tech" efficiency appliances, buildings and processes.

Starting from the needs of households, industry, transportation and other sectors for energy services, more adapted technologies can be identified with the chosen model structure which fulfil the energy service demand. This leads to a final energy demand met by an energy conversion sector which is disaggregated in as much detail as in the WEC scenarios. The scenario has been based on all worldwide databases for the supply and demand side (base year 1999) which were available at that time; however especially many data on technologies and costs of demand-side options are still missing; therefore, in many aspects the scenario had to be based on rough estimates and multinational regression analysis.

Following the general basic assumptions from the WEC/IIASA scenarios (e.g. concerning regional differentiation and development of GDP or population growth), the more end-use oriented scenario analysis of Factor Four:

- shows that climate protection and risk minimisation (e.g. nuclear phase-out) is possible;
- identifies the three "green pillars" of sustainable energy systems, namely priority for the rational use of energy (RUE), fostering the market introduction of combined heat/cold power production in industry and district heating (CH/CP) and increasing the share of renewables (REG);
- outlines possibilities and demands for technology transfer between industrialised and developing countries ("leapfrogging");
- identifies the co-operation between renewable energies with a fluctuating supply characteristic and other renewable or fossil energies which can be stored and used in a more flexible manner.

The main difference compared to WEC-C1 is that in the "Factor Four" scenario the historical rate of efficiency increase (about 1% p.a.) is doubled. Instead of 1.4% p.a. (WEC-C1) it increases to about 2% (p.a.) during the period 1990-2050. This increase and a 60% share of renewables in 2050 are sufficient for a risk minimisation strategy up to 2050; e.g. to reduce $C0_2$ by 50% by 2050 an energy productivity increase of "only" a factor three is necessary if the supply-side strategy is based on the "clean and green" mix of renewables and CHP.

The scenario shows that this increase is technically feasible. It seems plausible that accelerating efficiency increase and decentralised technical options will keep the total costs in the range of the least-cost strategy of the C1 scenario. One important policy to make this happen should be to change the incentive structure: Reducing the bill of the customer by increasing energy efficiency should be made profitable to the suppliers of energy as well. New framework conditions are needed to establish a fair level playing field where traditional final energy can compete with distributed power production and energy efficiency technologies. To put it into a popular phrase: Not only profits from “MEGAWatts” (selling kilowatt-hours) but establishing new markets for “NEGAWatts” (by Demand Side Management (DSM) or Integrated Resource Planning (IRP), e.g. selling energy services and efficiency equipment at least societal cost) are needed.

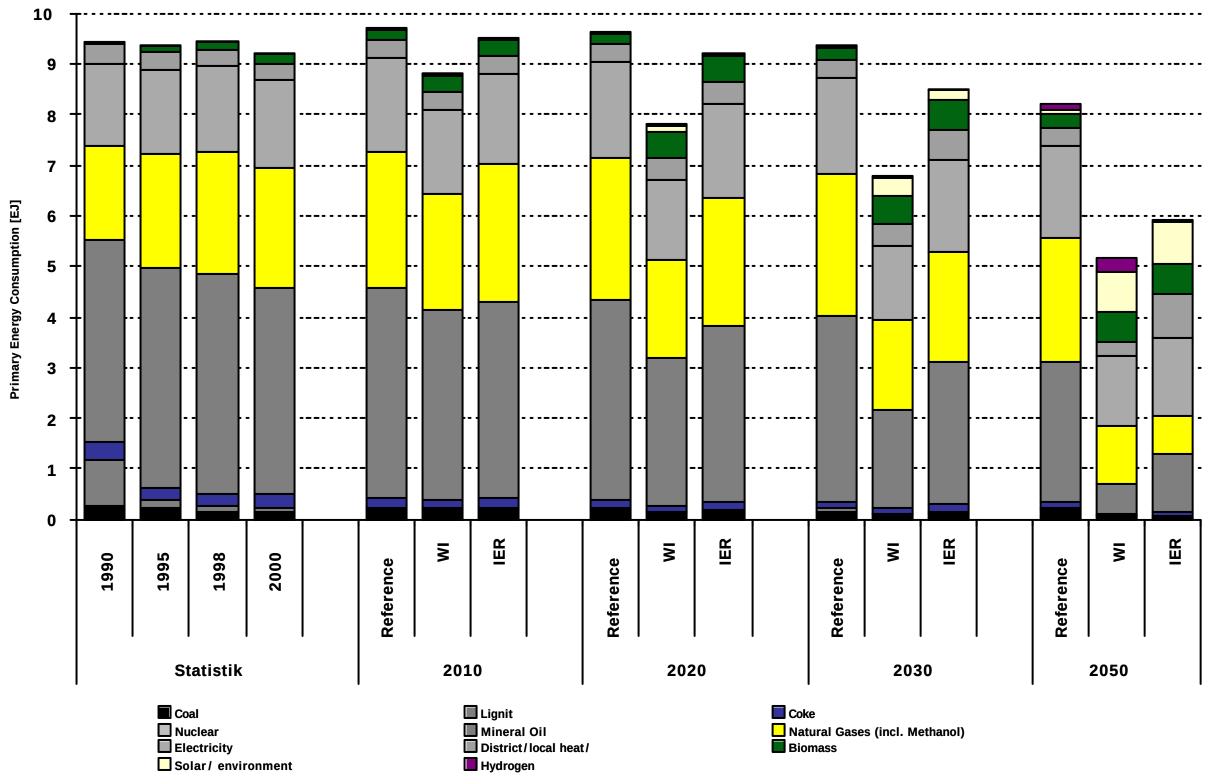
By comparing the “Factor Four” scenario not only with the WEC-C1 scenario but with other long-run sustainable world energy scenarios (Schrattenholzer 2001; for Germany see: Energy Enquete Commission 2002), a key policy message can be derived: An absolute de-linking of GDP growth and primary energy consumption seems to be technically feasible worldwide and for industrialised countries by increasing energy productivity. Giving highest priority to end-use energy efficiency and fostering the market introduction of renewables and combined heat/cold and power production (tri-generation) seems to be the key strategy for sustainable energy systems especially in the North, and with some adaptation, e.g. to the specific problem of rural electrification, for the cities and the commercial sectors in the South as well.

But what about the economic sustainability of ecologically sustainable energy systems? Some short remarks on this very complex question will be given based on case studies for Germany:

Case study II: Sustainable energy systems can be financed

Looking at recent macroeconomic analysis for sustainable energy systems in Germany (Energy Enquete Commission 2002), good arguments supporting strong and early climate protection actions and the phasing out of nuclear energy at the same time could be derived. Fig. 3 shows the structure of primary energy consumption compared to a reference case (“business as usual”/BAU) for two optional sustainable scenarios for Germany (IER vs. WI) which have been simulated with different models and different assumptions concerning the scenario philosophies. The scenarios are based on recent assessments of potentials and costs of all important supply and demand-side options for the German energy system (including learning effects and externals costs).

Fig. 3: Primary energy consumption (EJ) of a sustainable energy system in Germany (80% CO_2 reduction in 2050); different models: WI/Wuppertal Institute;



IER/Stuttgart

Source: Comission of Inquiry of the 14th German Bundestag on Sustainable Energy Supply, (2002)

Compared with a BAU/reference strategy, the discounted extra costs of the above-summarised sustainable energy strategy for the case of Germany have been calculated at between 10 to 150 Euro/per capita/a. Nuclear energy has been phased out and an ambitious CO_2 reduction goal of 80% up to 2050 has been simulated. This calculation does not include the huge reduced external costs within a sustainable energy strategy. Therefore one important message – even for countries like Germany with a high share of nuclear power production of 30% – can be derived from this kind of modelling: Risk minimisation – phasing out nuclear energy and reaching ambitious CO_2 reduction targets – can be technically realised and financed up to 2050. But: energy managers, politicians and the public at large – it is time to make up our minds! The decided phase-out of nuclear power is far from being irreversible (as the government has claimed) if the underlying alternatives (RUE, REN and CHP) within the scenarios are not introduced step by step into real markets. Within a BAU strategy (reference case), these results are definitely impossible. A completely new policy mix is needed, but it is economically feasible. If these scenarios are right, there will not only be no trade-off between higher costs now and avoiding damages tomorrow, the contrary would be true: Climate protection policy and risk minimisation create a double benefit to societies: first, to the living generation because the extra cost compared to business-as-usual is a cheap assurance in relation to the reduced risks; and secondly, to all following generations because the risks and damages of future global change will be minimised.

3. The economics of least-cost energy services

In spite of many differences between the worldwide and national case study, there is one important common feature: Without fostering the market introduction and market diffusion of end-use efficiency technologies, there is no chance for a sustainable energy strategy and for decoupling GDP growth from resource use. Of course, these beneficial impacts of end-use efficiency increase must be accelerated by more efficient power plants (especially based on co- or tri-generation). But as the Word Energy Council pointed out in its Final Statement of the Houston Conference (1998), the largest, the quickest and the most cost-effective option for reducing detrimental impacts on nature is increasing end-use efficiency.[17] Therefore a short excursion to the technologies, the barriers, the economics and the policies and measures addressing demand-side efficiency seems to be useful.

One of the challenges to defining concepts and instruments for sustainable development and climate protection is the so-called **micro-macro link.** Individual actors **need incentive structures, indicators and ecological crash barriers ("ökologische Leitplanken")** which encourage investment decisions in a sustainable direction and which harmonise individual and societal goals as far as possible. This is especially important to the discovery and implementation of "no regret" options for climate protection.

The rationale behind this kind of thinking can be shown by using **the concept of supply curves of conserved energy.** This concept is a useful screening tool **to develop markets for energy services** and to implement programmes in the context of **Integrated Resource Planning (IRP) and/or Demand-Side Management (DSM)**. It allows the direct comparison of the marginal costs of energy supply with the marginal costs of energy efficiency. This optimisation criterion is linked better to microeconomic theory, to the concept of energy service markets and to individual investment decisions than the concept of **CO_2 avoidance costs**, which may lead to non-optimal solutions.[18] In the following chapter we summarise the results of different bottom-up analyses[19] for the electricity sector of Germany.

Considering the wide range of efficient energy technologies which are already available on the markets, the insufficient degree of rational energy use seems to result from implementation deficits rather than from technology deficits. As the market for energy services (instead of kilowatt-hours) has not functioned up to now, one important question is how to overcome existing barriers.

From an analytical point of view, the observable degree of industrial energy efficiency represents a mix of different influencing factors, interactions and dependencies, incorporating all kinds of motivation and information deficits, barriers or market imperfections.[20] In order to avoid a misinterpretation of the trend scenario and of the possibilities to deviate from this path, the analysis of theoretical potentials has to be supplemented by the analysis of real adoption processes and resulting policy options. Otherwise, a systematic under- or overestimation of the contribution made by efficiency options and their impact on CO_2 mitigation would take place, causing wrong conclusions for energy policy-making.

In order to optimise the energy system in terms of emissions and costs, all different options both on the supply side and on the demand side should be systematically compared on the basis of long-run marginal costs, representing the long-term transformation costs of the energy system. Energy supply and energy conservation options both can be presented and compared by supply

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17 Recent scenario analyses for the German Bundestag and the German Environmental Agency (Umweltbundesamt) have shown that about 75% of an ambitious $C0_2$ reduction target of 50% by 2030 has to be realised by increasing end-use efficiency. Compare: Comission of Inquiry of the 14th German Bundestag on Sustainable Energy Supply (2002)

18 See Wuppertal Institut e, Öko-Institut, Fraunhofer Institut/ISI, (1997)

19 See, for example, Wuppertal Institute (1997).

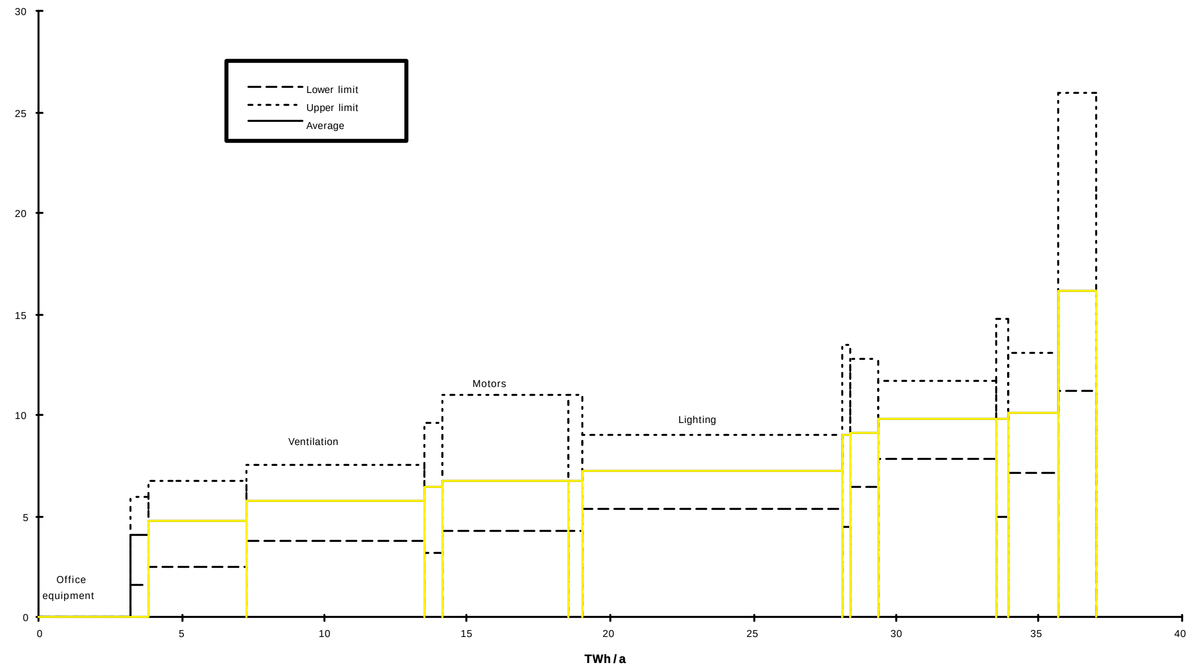
20 Cf. DeCanio 1993, Energie & Klima 1990, Gruber et al. 1995, Gruber/Brand 1991, IEA 1995, Sanstadt/Howarth 1994, Krause et al. 1993

curves containing the absolute potential (e.g. in GWh) and the specific long-run marginal costs (e.g. in Pfg/kWh) (see Fig. 4).[21]

The supply curves of conservation illustrate the maximum cost-effective savings potential under idealised market conditions. The average technology currently on the market has to be taken as the baseline for potential savings. The specific costs saved by efficiency technology represent the additional investment and operation costs of the best available equipment as compared to the average on the market (e.g. compact fluorescent lamps vs. incandescent light bulbs). Due to the fact that all efficiency technologies considered are already available on the market, they have passed a certain commercialisation process and have left the stage of pure theoretical technical potentials without economic relevance. Analogous to the treatment of supply-side options, the levelised costs of conservation potentials have to be spread over the energy saved during the lifetime of the efficiency technology. The analysis is an idealisation in the sense that a macroeconomic discount rate (e.g. 4% in real terms) is used to level out the additional costs of energy-efficient technologies compared to business-as-usual technologies. Figure 4 shows a conservation supply curve for the commercial and service sector as an example. Similar supply curves for the industrial and residential sector have been calculated by the Wuppertal Institute and others (see below, the Case Study Hanover).

[21] For underlying data see Wuppertal Institute/Öko Institute 1995, furthermore e.g. A&W/Haas Consult 1994, Berg 1992, Brunner et al. 1988, Brunotte 1993, ESource 1992, ebök 1988, Fischli 1993, Ravel 1992, Horbaty/Renggli 1993, Humm/Gasser/Bush 1991, Huser/Eisenhut/Bush 1992, Kaufmann/Ackermann/Pauli 1992, Münst 1992, Öko-Institute 1992, 1994, RAVEL 1991, 1992, 1993, Schäfer 1994, Sigg 1994.

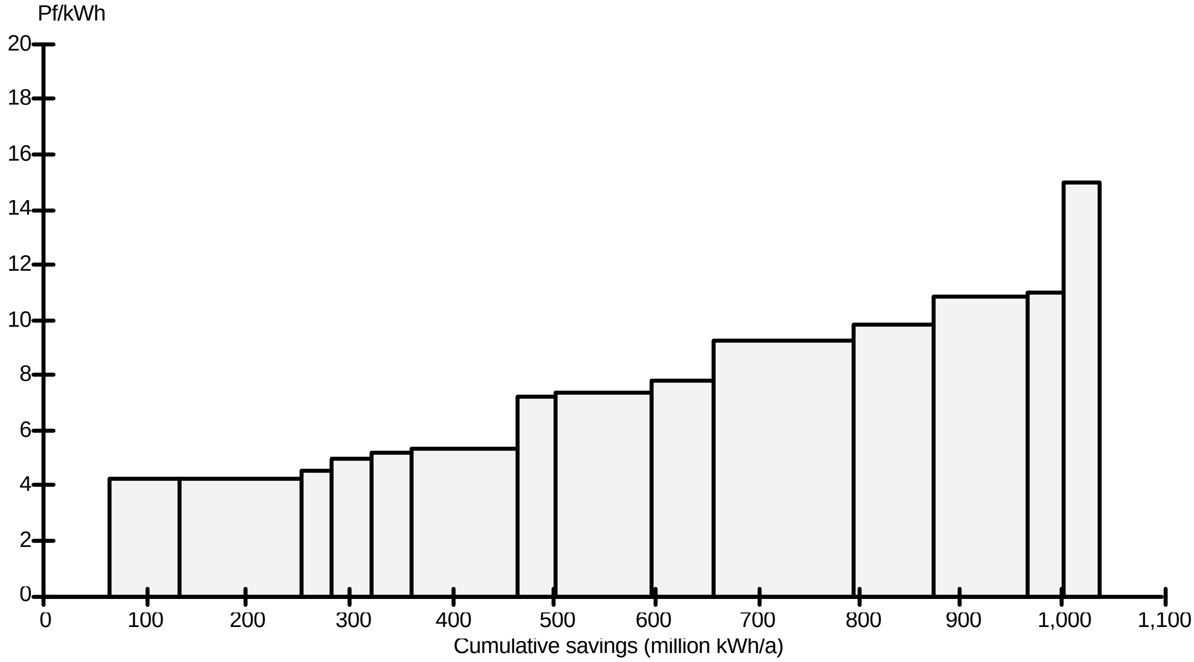
Fig. 4: Supply curve for electricity conservation in the German commercial and service sector (total consumption 103,4 TWh in 1992)



From these supply curves, a (macro-economically defined) least-cost mix of energy options satisfying a given demand for energy services can be derived. For this purpose, transaction costs must be added, and the total costs of "NEGAWatts" must be compared with the total system costs of electricity ("MEGAWatts"). Up to now, there are not too many hard figures for transaction costs in Germany. The main reason is that while there are a lot of pilot programmes (about 500), there are not so many evaluated full-scale programmes in Germany. If you add on average 30% to technique costs for transaction and marketing, there will nevertheless be a huge potential of NEGAWatts which should be cost-effective if the barriers to implementation could be overcome.
Therefore, an important conclusion can be derived: Within the boundaries of national and international CO_2 abatement targets, **unimpeded competition between energy and capital (efficiency technologies) is at least as important as direct competition between energy suppliers**. To reach a specified level of national energy services with least costs (not only cost-effective energy supply) should be at the core of energy policy. Within this concept, supply curves of conservation potentials represent a useful screening tool for defining least-cost options of energy policy and for analysing the size and the structure of a market for energy efficiency.
Figure 5 shows an aggregated supply curve of conservable or substitutable electricity for the city of Hanover,[22] which seems to be representative of the total electricity sector in Germany. This supply curve is part of the most comprehensive case study on the feasibility of Least-Cost Planning/Integrated Resource Planning in Europe. Meanwhile, **the framework for the implementation** of IRP in the liberalised European market has changed. With direct retail competition, specific framework conditions and financial mechanisms (e.g. a non-bypassable fee on all kilowatt-hours sold) are necessary so that **energy service companies involved in IRP and selling energy services** are not priced out of competitive markets.[23] In Germany it is debated whether to give utilities the choice of either investing a certain amount of their revenues (say 3%) into IRP programmes or transferring the money to a national fund (Energy Efficiency Fund). The fund organises competition for least-cost efficiency programmes on a national scale.
In that context the screening tool of the supply curve of conservable or substitutable electricity could even be more important as a method to discover and evaluate new markets and business activities in liberalised markets.

22 Öko-Institute/ Wuppertal Institute (1995)
23 See Wuppertal Institute et al. (1999)

Fig. 5: Supply curve of conservable or substitutable electricity for Stadtwerke Hanover (consumption in 1991: 3,027)



In 1996, about one third of electricity used in Hanover could be conserved (cf. Fig. 5) at costs lower than the long-term marginal system costs of electricity supply (including avoided fixed and variable costs of generation, avoided losses, and avoidable costs of electricity transport, distribution, and sale). Under the specific conditions **at that time**[24] in Hanover, avoided costs ranged between 0.07 and 0.086 ECU/kWh (13 and 16 Pf/kWh without internalisation of external costs).

4. Closing the implementation gap: Instruments for sustainable energy paths

The scenarios presented above have shown that in principle an adequate pool of technological options is at hand to provide a level of energy services that is climatically acceptable and entails a minimum of risks. The crucial question, however, concerns the issue of which instruments can be applied to break down the barriers impeding market implementation of efficiency and risk minimisation policies, and thus remove the innovation and investment blockages currently standing in the way of more "soft energy paths".

The German Enquete Commissions have shown beyond doubt that the challenging CO_2 reduction targets set for Germany (30% by 2005, 80% by 2050) can only be achieved by a **comprehensive and differentiated policy mix.**[25] For example policy mixes have been investigated for the important target group of small and medium-sized enterprises (SME) in more detail.[26] Promising policy mixes have to include measures concerning:

- increasing general motivation (especially at top management level) (e.g. Bush 1996, Institute for Energy Technology 1995);
- supplying specific efficiency know-how and information including multipliers, e.g. RAVEL Impuls programmes in Switzerland and NRW, Germany (Energieagentur NRW 1996, RAVEL 1996);

[24] Meanwhile under competive pressure electricity prices in Germany have decreased on average by 10-20%. But in markets for energy services the long-term marginal cost of electricity conservation will decrease too, whereas the price of electricity supply will increase when more external costs are internalised or gas prices go up.

[25] The author has been a member of three Commissions of Inqiry of the German Bundestag (two on Climate Protection and one on Sustainable Energy Systems). Commissions of Inquiry are established by the German Bundestag as advisory bodies during an election period. Members (about 20-25) are experts form academia (about 50%) selected by the major parties of the Bundestag and Members of Parliament (about 50%). The rationale behind this mixture of experts and politicians is to channel new scientific and technical research directly into the decision-making process of parliament. Compare Comission of Inquiry of the 14th German Bundestag on Sustainable Energy Supply (2002), Commission of Inquiry of the 12th German Bundestag on Protecting the Earth´s Atmosphere (1994)(both only available in german language)

[26] See Wuppertal Institute et al (1998).

- financial incentives, e.g. contributions to energy audits, utility rebate programmes (IRP/LCP), contracting (Wuppertal Institute/Öko Institute 1995, European Parliament 1996);
- innovative (pre-)financing of cost-efficient energy efficiency programmes and actions by establishing, for example, energy savings funds by non-bypassable fees on electricity or natural gas revenues;[27]
- fostering implementation know-how by technical assistance and dissemination of best practice cases, e.g. by utilities, energy agencies and efficiency awards (VIK 1996, Lupi/Innocenti/Serani 1997);
- increasing organisational know-how by energy and environmental management systems providing information on potentials and costs;
- market transformation strategies increasing the (average) efficiency of equipment sold, e.g. by (combination of) standardisation, labelling, negotiated target values or technology procurement (Bundesamt für Energie 1996, Westling 1996);
- establishment of supporting (local) social networks, e.g. energy management models (Bürki 1990).

In addition, a significant impact on energy efficiency can be expected from new multi-dimensional policy strategies combining stringent policy intervention with co-operative elements. Such a promising approach can be found in Denmark, where the recently introduced Danish CO_2 tax scheme subjects firms to a dynamic CO_2 tax, which can be lowered by a certain group of companies from energy-intensive branches if individual energy concepts are negotiated (MoF 1995).

In general, strong political guidance must be given and political decisions must be taken that put developments on the right track if climatically acceptable future markets are to be tapped in time and to a sufficient extent. The concurrent shrinking of risk-burdened markets (for fossil or nuclear energy) and the politically induced emergence of 'soft' markets (e.g. for energy-efficient universal technologies on the user side – in electric drives, ventilation, pressurised air, lighting; for renewable sources of energy; for low-energy houses; or for combined heat and power generation) demand long-term planning security for investors – something that can only be created through framework conditions set by the state. "Deregulation" and "liberalisation" of the energy markets need political leadership and a framework that can lead markets, competition and profits in a sustainable direction. The guiding ideas of an economic policy for a new **combined regime of self-control and state regulation** in the energy system are: 'planned competition', 'economy of prevention', 'efficiency revolution' and 'new models of wealth'. The fundamental idea of a profit-driven energy-efficient economy is: The prevention of unnecessary consumption of energy and resources must not only provide benefit to the customers, but also to the suppliers – and to the same extent at least as an additional supply of energy and resources. Failure to give the profit-orientation of individual economic actors a new, ecological market and development perspective must leave ecology and economy incompatible in a profit-driven market economy, and objectives such as climate protection and sustainability would remain unachievable in market economy systems.

Taking energy taxation as an example (of a first module of ecological tax reform): If well designed, this market-oriented instrument acting via relative prices ('bads' become more expensive while 'goods' become cheaper) can accelerate the ecologically necessary structural change in a manner that is more conducive to a thriving economy and social equity than laissez-faire policies. Macroeconomic studies provide further evidence that a gradually rising and revenue-neutral energy tax will tend to trigger positive effects on the overall economy (more employment, more qualitative growth). As long as no OECD-wide introduction of such a tax is on the horizon, it does remain purposeful, though, to use limited exemptions or transitional provisions to cushion the adjustment losses inevitably experienced by individual industries in any structural change.[28]

That these positive macroeconomic model results point in the right direction is verified by empirical evidence, and also by an overwhelming body of potential studies. The empirical evidence shows that the growth rates of demand-side and supply-side energy efficiency products have consistently been about twice as high as those of manufacturing over the past 10 years.[29] In the 1990s, this lead lengthened.

Present environmental protection expenditure in Germany (44 billion DM in 1993) is, however, still largely made up of end-of-pipe technologies, which lead to new markets and returns for the manufacturers, but generally to extra costs for the users (e.g. flue gas purification equipment for

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28 Cf. Görres/Ehringhaus/ Weizsäcker (1994).
29 Schmidt (1995).

power plants). An ‘Economy of Prevention’, by contrast, relies primarily upon ‘integrated pollution control’, i.e. upon technical innovations that control processes and products in such a way that the user, too, receives material, energy and cost savings in general, which provide the basis for an improved competitive position.

This explains the major relevance of economic policy to improving energy efficiency in conversion and use. It has been estimated that up to 45% of Germany's energy consumption could be saved with the technologies that are already known today.[30] With today's energy price level, this could cut the macroeconomic energy bill by some 50 billion Euro per year. The tapping of this savings potential could create half a million secure jobs (net after deduction of losses suffered in the energy supply sector). There are still some doubts among energy experts as to the economic feasibility of this veritable ‘efficiency revolution’, but the technical feasibility is no more debated. One important point is that the “efficiency revolution” contributes to the de-globalisation of energy service markets, because CHP systems for municipalities and industry, renewable energy and efficiency equipment (mainly in buildings) create local and regional markets. It's an import substitution strategy: imported oil, gas or coal and the flow of money outside the economy is substituted by endogenous resources and local value added.

But only rediscovering and actively exercising the primacy of energy policy can bridge the widening gap between knowledge and action. Unlike on the energy supply side, frameworks must be judiciously set and vigorously supported by all agencies of the state if energy consumers are not to dictate much too high energy consumption in the future by daily undertaking thousands of energy-inefficient investments.[31]

In contrast to the highly powered supply side, energy conservation has no lobby. Up to now, energy users, efficiency manufacturers and NGOs only have marginal influence on developing markets for energy services. Investments in more energy supply are calculated with payback periods of 15 and more years, while energy-saving investments must pay back from the perspective of the users within 3-5 years at most. As a consequence, without state intervention there is a steady flow of too much capital into the expansion of supply. Therefore, without appropriate supporting regulatory policies, the implementation of NEGAWatts instead of MEGAWatts has little chance of succeeding in the struggle against the prevailing perverse incentive structure: At present, the more energy a utility sells and thus also damages the environment, the higher its profit is. The opposite should and could be the case: Earning more with less energy. This is the applied “Economy of Prevention”.

5. The eco-efficiency revolution has started

Fostering the increase in energy productivity is not the only key to sustainable development and the implementation of the “Factor Four” concept. A broader understanding of “resource productivity increase” (including all material flows and energy) is needed to reduce costs and negative impacts on the environment.

It is widely believed that “productivity” growth is somewhat like the engine that drives overall well-being. The more productivity, the better for society – that's a well-known message for policy makers and business people. But which kind of productivity should grow and what direction of economic growth is sustainable? Although productivity sounds like a comprehensive and multi-dimensional concept, it is usually restricted to labour productivity. Since the beginning of the industrial revolution in the nineteenth century, western industrialised countries have witnessed a productivity growth of a factor ten (UK) or even forty (Japan) (Maddison 1995). Nobody will deny that increasing labour productivity has its economic merits in times of labour shortages. Unfortunately, these bright times are over. In harsh times with some 18 million people unemployed in the European Union, rationalising labour may be profitable from the perspective of short-run shareholder maximisation. But it is not a wise strategy for the economy as a whole and in the long run disastrous for the legitimacy of global capitalism. From the perspective of responsible entrepreneurs and sustainable democracies, technical progress should be as nature conserving and labour augmenting as possible – and not labour saving. With this vision in mind, new types of social innovations and of technological progress are desired.

In the view of the Wuppertal Institute, the traditional emphasis on labour productivity ought now to be widened or even transformed towards increasing eco-efficiency. The concept of multi-factor productivity ought to include the productivity of natural resources and material flows[32]. By still looking after the increase in labour productivity while speeding up resource productivity, countries which have high levels of unemployment and which are faced with environmental problems could become richer. Economies can revitalise by disseminating best practices, by stimulating innovation, by setting up new ways of efficient management and organisation, and by investing in human and social capital. Keeping within the natural limits to growth (“crash barriers”) and decreasing

[30] Enquête-Kommission “Schutz der Erdatmosphäre” des 12. Deutschen Bundestages (1994)
[31] Hennicke/ Richter/ Schlegelmilch(1994).
[32] Bleischwitz (1998)

economic and environmental risks will lead to new markets and business opportunities.[33] Regulation, if properly designed and incentive-oriented, can offer powerful dynamics to the evolution of new technologies and eco-efficient products and services. A concept like Factor Four, i.e. increasing economic prosperity while reducing the use of natural resources, combines different governance arenas as a decision rule that makes people smart and reduces uncertainties for business makers. Taken together, technological-economic change and sustainable development may coincide to a greater degree than is usually expected.

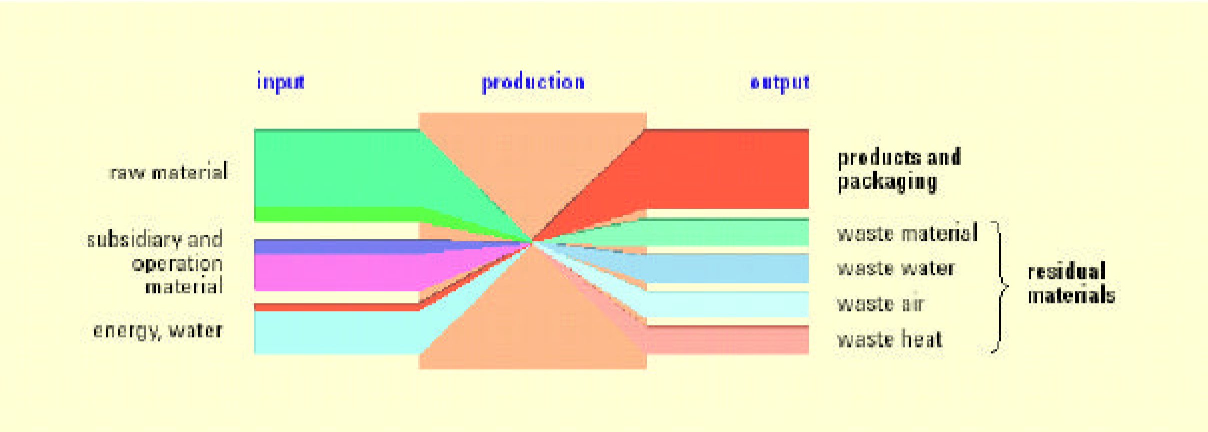
The ongoing debate on sustainability and on "greening" resource productivity has led to designing and spreading many good-practice examples. These examples include highly efficient production processes, appliances, lighting, motor drives, ultra light cars using less than 2 litres per hundred kilometres (e.g. Lovins' "Hypercar"), or "passive house" buildings ("Factor Ten" reduced energy consumption). This eco-efficiency revolution means a "quantum leap" for productivity increase and a new direction of technical progress. The new direction could increase the market share for products which meet criteria of low or zero emissions, low waste, zero toxic dispersion, etc. Additionally, elements of reuse, recyclability and durability are to be integrated, leading to better materials and new product design. For business, eco-efficiency assists companies in their quest for continuous improvement in minimising their use of resources, lowering costs and being more competitive. It encourages creative strategies of preventative management by integrating environmental considerations throughout the whole life cycle of products and promotes an active shift to multi-use products and services and other use concepts ("use instead of own"). In doing so, it involves many stakeholders and creates tangible economic benefits. Companies actively enhancing eco-efficiency are able to improve their product design, procurement, manufacturing processes, product maintenance and their customer relationships. A longer durability will reduce the number of products sold while increasing their individual value and supporting activities of repairing and remanufacturing. New and additional types of eco-efficient services will occur: among producers, broker agencies and specialised companies will deal with reusing materials and product components and with operating heating and cooling systems generated by nearby sources. Financial services for high-quality goods will offer opportunities for those reluctant to invest in high-priced goods (with lower running costs). They will also pre-select supply options and press producers to increase the lifetime of their goods. A third type of new service is related to information and communication. Companies and consumers have strong preferences for better information about eco-efficient innovations, helping them to lower their costs. Any leasing and sharing of goods used only for a certain time (e.g. cars) will be assisted by communication systems offered by SMEs or larger companies. No wonder that the concept of sustainable enterprises gains – in one form or another – more and more acceptance.[34]

After all, compared to costly end-of-the-pipe technologies, this new direction of resource-saving technical progress is economically beneficial and is integrated into the entire value chain. It stimulates the cooperation within industry as well as between industry, services and the public sector. Such a development will nevertheless *not* lead to a non-industrial service economy, but rather to a service-driven industrial society with less material and energy-intensive production and consumption ("dematerialisation"). If one likes to put it emphatically: the coming age of resource productivity with low information prices and quality production could supersede the contemporary age of labour productivity with low energy prices and mass production of goods.

The economic potential of fostering resource productivity can be demonstrated for the case of Germany by some rough figures:[35] Under the pressure of competition and economic crisis, most companies focus on fostering labour productivity and on dismissing people from their jobs. But this kind of rationalisation by reducing labour costs does not increase competitiveness in the long run by innovative processes and products. In many cases it would be more cost effective if energy and material were to be rationalised by producing more added value with less resource use. Ernst von Weizsäcker has put this idea into the phrase: "We should fire tons and kilowatt-hours not people". It has been demonstrated for German industry that about 180 billion Euros p.a. are spent on residuals (energy, waste water, waste, etc.) which create no added value but only costs (see Fig. 6).

[33] Compare Hennicke (2002)
[34] Word Business Council for Sustainable Develoment (WBCSD) (2002)
[35] See Fischer, H., Leute rauswerfen kann jeder, in: die ZEIT 26/2002.

Fig. 6: Residual materials – The link between costs and environmental protection



Residual materials cause environmental strain.
Residual materials cause costs.
When purchased they are paid as input material; then, after being stored and transported, they take up production capacity; afterwards, they are recorded again, treated and then usually given to a third person (disposal, utiliser) with costs.
Residual materials are a strain on the environment and business profits.

Graph: Wuppertal Institute (2000); Source: Kienbaum Unternehmensberatung GmbH

The main cost factor within industry is no longer caused by labour, but by material and energy: about 180 billion out of 730 billion Euros for material and energy could be avoided by eco-efficient processes without a loss to the quality of goods and services. The average household in Germany causes a throughput of 11 t material and 9 t of oil per year. Food, clothing, mobility, heating, etc., could be supplied with at least 25% less material and energy and without a decrease in living standards if all existing best available technologies were to be used. On average, this adds up to 5,000 Euros per household and in total to the above-cited costs for residues of 180 billion Euros.

As demonstrated, the employment effects of implementing this eco-efficiency potential and of coupling technical progress with "green" resource productivity will most likely be positive.[36] One reason is simple and straightforward. New environmentally benign goods and services emerge and will improve competitiveness and employment. Besides these qualitative growth effects, the increasing attempts to enhance eco-efficiency would lower the pressure to rationalise labour alone. A push towards sustainability and resource productivity will stimulate learning processes and investments towards new technology paths. These new paths will partly consist of high-tech products. Recycling activities, for instance, can still enhance their labour productivity. But a significant additional share will be labour intensive resulting from repairing, remanufacturing and various other service activities. These activities normally require technical as well as communicative skills. Relatively low skills are required for processes like returning, dismantling, sorting, cleaning and repairing as well as for some communication activities in the eco-efficient service sector. These low-skill activities will contribute to a labour augmenting technical progress. In some cases (e.g. organic farming), human labour might even directly substitute current energy and material intensive processes.

As the direction of technological progress gradually changes, the employment threshold will stagnate or even come down. This would mark a break in ongoing trends. Lowering the employment threshold would add substantial benefits to the employment situation, if the overall expectation for productivity is strong enough to stimulate further investments. What economies might aim at is a resource productivity which has a higher growth rate than the overall (qualitative) growth rate of GDP which, in turn, should be higher than the average increase in labour productivity.

6. Politics must set the rules – innovative regulatory policies

The new direction of technical progress cannot be driven by autonomous technological progress, unregulated markets and maximising short-run profit margins of companies as mainstream economics might believe. Instead, national governments and worldwide governance under the guidance of the UN must take the lead. A policy mix, combining (re)regulation with innovative market instruments, and global with specific sector and target group instrument bundles are needed. "Laissez-faire" and unregulated markets will not bring us to functioning competition,

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[36] Fischer assumes that at least 700,000 new jobs (net) could be created by avoiding the above-mentioned costs for residues of 180 billion Euros (material and energy; oral communication).

responsible entrepreneurship and sustainable development.[37] In addition, resource productivity has a strong tie to consumers' demand and societal values. Consumers are relevant to the demand for quality goods, energy-efficient appliances and their individual use. They might also practise new patterns of sharing goods, thus reducing the overall number of products produced. In this context, the factors of technology push and consumers' pull fit together almost smoothly. Increasing services means also a better cooperation among producers and with consumers and their individual needs. Moreover, the principle of durability extends the product life cycle and will certainly help to overcome the short-sightedness of many contemporary economic processes. Against this background, eco-efficiency is not in opposition to any sufficiency and a sustainable civilisation, but rather a supporting and co-evolutionary activity. Experience and tradition might come back as individual and societal values. Increasing resource productivity might hence facilitate new models of wealth based upon cooperation, learning, solidarity, calmness and prosperity in time (rather than in products).

Therefore, the eco-efficiency revolution will not succeed on a broad scale unless the framework conditions for doing green business are changed. Reducing resource flows and energy must be made profitable – obtaining more services and well-being from less resource consumption. Politics should change the incentive structure to an "economy of prevention", and new models of wealth should be encouraged by pilot projects, education and social marketing campaigns. On the other hand we should not "wait and see" what political actions are taken, because to an astonishing extent eco-efficiency is profitable now.[38] Eco-pioneers and those companies undergoing eco-auditing procedures have discovered that through innovations and through transparency they gain from the link between materials and energy on the one hand and financial and knowledge flows on the other. All this has led to promising experiences that a portfolio of "green" stocks can perform even better on the international stock markets than the MSCI index.

It is nevertheless to be feared that the scope for resource productivity will be narrowly limited if the present market conditions prevail. These are characterised to a large degree by the cognitive and institutional bias towards old-fashioned manufacturing processes and cheap nature. As a result, one sees an incredible amount of subsidies going into natural resource consumption and labour rationalising activities. As Andre De Moor,[39] then with the Dutch Institute for Fiscal Studies, has estimated, some 700 billion dollars are spent worldwide annually in agriculture, energy consumption, water and motor transport. This does not yet account for all the tax advantages, free infrastructure and land given to the investor. Nor does it account for certain public policy programmes intended to drive an economic upswing, but which essentially transform nature into cement while having doubtful economic success. De-subsidising resource use will thus become an important policy worldwide.

A related policy tool is the ecological tax reform. In the current world of mass unemployment (in many countries) and of scarce natural resources, it does not make sense to draw the biggest share of fiscal revenues from labour while resource use goes essentially free of charge. Almost all EU membership states have adopted some kind of eco-taxes since the late nineties. Ideally, the aim might be a moderate but steady increase in resource prices. Such an increase would lead to further innovations and cumulative effects. If designed together with other tax reductions and incentives to create markets for efficiency and renewables, the overall effects on international competitiveness would not be insupportable. There is both increasing theoretical and empirical evidence from economics (Oates 2002) that fiscal and regulatory competition resulting from unilateral action contribute to increasing institutional efficiency and will not have dramatic effects. Nakata and Lamont (2001) arrived at similar conclusions for the impact of carbon or energy taxes on Japan. And this might hold true for GHG emissions trading schemes as well. But a caveat should be added: Internal (within multinational companies like BP or Shell) and national GHG emissions trading schemes should not be institutionalised, but instead closely integrated into existing climate protection policies and measures.

To conclude: Looking ahead in the new millennium, a new paradigm for "green" technological progress and models of wealth is needed if one wants to successfully tackle challenges of (qualitative) economic growth, environmental concerns, unemployment, ageing societies and the unequal distribution of wealth and living standards. In spite of many remaining uncertainties, the general idea of increasing eco-efficiency seems to be a robust and necessary first step towards sustainability.

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[37] See Comission of Inquiry of the 14th German Bundestag on Sustainable Energy Supply (2002)

[38] See WeizsäckerLovinsLovins (1998)

[39] See De Moor/ Calamai (1997)

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