Europäische Akademie

zur Erforschung von Folgen wissenschaftlich-technischer Entwicklungen
Bad Neuenahr-Ahrweiler GmbH

Direktor:
Professor Dr. Carl Friedrich Gethmann

Sustainable Development and Innovation in the Energy Sector

Executive Summary

by

U. Steger, W. Achterberg, K. Blok, H. Bode, W. Frenz, C. Gather, G. Hanekamp, D. Imboden, M. Jahnke, M. Kost, R. Kurz, H.G. Nutzinger, Th. Ziesemer

February 2003

Graure Reihe Nr. 33

Europäische Akademie

zur Erforschung von Folgen wissenschaftlich-technischer Entwicklungen
Bad Neuenahr-Ahrweiler GmbH

Direktor:
Professor Dr. Carl Friedrich Gethmann

Sustainable Development and Innovation in the Energy Sector

Executive Summary

by

U. Steger, W. Achterberg, K. Blok, H. Bode, W. Frenz, C. Gather, G. Hanekamp, D. Imboden, M. Jahnke, M. Kost, R. Kurz, H.G. Nutzinger, Th. Ziesemer

February 2003

Graue Reihe Nr. 33

Publisher:

Europäische Akademie

zur Erforschung von Folgen wissenschaftlich-technischer Entwicklungen
Bad Neuenahr-Ahrweiler GmbH

Wilhelmstraße 56, D-53474 Bad Neuenahr-Ahrweiler
Telefon: ++49 - (0)2641 - 973 - 300, Telefax - 320
e-mail: europaeische.akademie@dlr.de
www.europaeische-akademie-aw.de

Director:

Professor Dr. Carl Friedrich Gethmann (V.i.S.d.P.)

ISSN 1435-487 X

Editing:

Dipl.-Päd. Sevim Kiliç

Print:

Warlich Druck Ahrweiler GmbH, Bad Neuenahr-Ahrweiler

FOREWORD

In September 2000 the Europäische Akademie installed the project group, Sustainable Development and Innovation in the Energy Sector'. The aim was to bring together economic, legal, scientific and philosophical competencies with a view to developing proposals for the relevant policy fields. This task requires clear focusing on the intersection of the three central issues, i.e. energy, sustainable development and innovation. Members of the study group were: Ulrich Steger, Chair, (IMD Lausanne), Wouter Achterberg † (Applied Philosophy Group, Wageningen Agricultural University and University of Amsterdam), Kornelis Blok (Department of Science, Technology and Society, Utrecht University), Walter Frenz (Lehr- und Forschungsgebiet Berg- und Umweltrecht, RWTH Aachen), Dieter Imboden (Umweltphysik, Institut für Gewässerschutz und Wassertechnologie, ETH Zürich), Rudi Kurz (Institut für Volkswirtschaftslehre der Fachhochschule Pforzheim), Hans G. Nutzinger (Fachbereich Wirtschaftswissenschaften der Universität GH Kassel), Thomas Ziesemer (Maastricht Economic Research Institute on Innovation and Technology [MERIT], Universität Maastricht).

Until May 2002 the group prepared a report that was presented to the public in October 2002. The work of the group was peer-reviewed on the occasion of two work-shops. One in January 2001 concerning the working program, the other in November 2001 reviewing a first draft of the final report. Participants of these meetings were: Wilhelm Althammer (Leipzig Graduate School of Management), Nicholas Ashford (MIT), Gerd Eisenbeiß (Research Center Jülich), Brigitte Falkenburg (University Dortmund), Volker Radke (University of Cooperative Education Ravensburg), Klaus Rennings (ZEW Mannheim), Herwig Unnerstall (Center for Environmental Research Leipzig-Halle) Alfred Voß (University Stuttgart), C.-J. Winter (Energon).

This booklet contains an English translation of a summary of: U. Steger, W. Achterberg, K. Blok, H. Bode, W. Frenz, C. Gather, G. Hanekamp, D. Imboden, M. Jahnke, M. Kost, R. Kurz, H.G. Nutzinger, Th. Ziesemer : Nachhaltige Entwicklung und Innovation im Energiebereich. Volume 18, Springer-Verlag, Berlin, 2002, ISBN 3-540-44295-2. This publication may be ordered from the publisher under www.springer.de. Order forms are also available at the Europäische Akademie.

Bad Neuenahr-Ahrweiler, February 2003

Gerd Hanekamp

CONTENTS

Executive Summary

Introduction

The discussion seems to be paradox: Almost every energy scenario is based on trends that would lead to an enormous growth in the demand for energy in the coming decades. Meanwhile, at international conferences, among other places, one is concerned with the opposite outlook; a massive reduction of greenhouse gas emissions, especially of CO_2 emissions caused by energy consumption. Experts also point out the political risk of depending on mineral oil and remind us of the fact that resources are not inexhaustible. How can this chasm be overcome? How can we build a more sustainable energy system from the existing one? Hopes are mostly pinned on technological progress and innovations.

However, so far there are no specific suggestions concerning the extent to which innovations can really contribute to reconciling ever-growing energy consumption with the limitations regarding the availability of resources and the environment, as well as with the structural demands on any energy system.

The aim of this study is to bring together economic, legal, scientific and philosophical competences with a view to developing such proposals. This task requires clear focusing on the intersection of the three central issues, i.e. energy, sustainable development and innovation. A comprehensive treatment of the three subject fields was not intended. Neither could many of the debates in this context be dealt with beyond their relevance for the strategy proposal of this study.

In deriving our recommendations, the aims laid down by democratically legitimized agencies were taken into account, no matter how vague these aims are, especially on the international level. An important part of our work concerned the analysis of conflicting objectives in economic policy and the question of how such conflicts can be overcome through a more comprehensive, incentive-based mix of instruments tailored to the specific substance of an innovation.

Terminological and conceptional foundations

Since a sound investigation cannot be performed without a clearly defined terminological and conceptional framework, we will start by inspecting the central concepts of sustainability, energy and innovation.

The idea of sustainability with its two normative cornerstones of intra- and intergenerational justice has to be made concrete especially for the area of energy which is based mostly on exhaustible energy sources. Instead of a static concept of stocks, which conceptually excludes a sustainable use of limited resources, a dynamic concept of flows (current use) is introduced, which is based on the substitution of non-renewable resources by renewable ones and on the continuous creation of new, more efficient ways of using resources. In this way, the need for innovations in this area is, at least implicitly, addressed. If, by appropriate innovations, one succeeds in reducing the use of exhaustible resources in production and consumption, so that a lower consumption of such limited stocks will suffice in the future, the chances to utilize such declining resources can be maintained or even improved in some cases. The *possibility* of such chances, however, does not imply that, faced with the present trends in the areas of energy use, strains on the environment, private consumption and population development, a path of "sustainable development" can *actually* be found.

For the sake of clarity, our analysis distinguishes between *sustainability* and *sustainable development*: The regulative idea of sustainability initiates and accompanies, with a practical intention, a search and learning process which leads to the more concrete concept of sustainable development, whereby potentials and possibilities for action towards sustainability can be identified; hence sustainable development is regarded, in principle, as a guide for action.

Considering the multitude of efforts to define "sustainable development" – by now there are more than 200 of them after fifteen years of scientific and political discussions –, one cannot but admit that this concept is still very vague or, sometimes, even mired in confusion. In the present discussion of the problems surrounding sustainability, a first approach leads to the observation of three different ways of dealing with the varied meanings of “sustainable development”: Apart from sheer *disapproval* (because of the “wooliness” of the concept) and an *integrative strategy* (by burdening the concept with everything that happens to suit one’s purposes), there is another possible attitude which is shared by our group: the effort to deal with the concept in a *productive* manner and to define it as precisely as possible according to scientific criteria. This involves comparing various possible definitions of the concept and asking the question which concrete conclusions follow for the central research question of our investigation for each case. This path is taken in neoclassical environmental economics on the one hand and especially by ecological economics, the “science of sustainability” on the other hand. One has to find a balance between overdetermination and underdetermination of this concept and one should neither burden it with specific requirements which meet the most stringent ecological criteria, but make it an unachievable ideal, nor should one leave it so vague that it can mean everything and effect nothing: In principle sustainable development must be an operational concept.

The various concepts ranging from “weak” to “very strong” sustainability differ with regard to assumptions about substitution and complementarity between man-made and natural capital. This study applies the concept of critical sustainability based on a concept of critical natural capital, taking into account few, but crucial and hence critical “crash barriers” or “bottlenecks”. Our interpretation of sustainability thus is related to the far-advanced discussion of setting environmental standards.

Energy may determine our everyday life and constitute an important production factor in economic theory; from the physics point of view, however, it is a rather abstract entity which can only be defined accurately in terms of a differentiated mathematical model. Historically, the concept of energy was initially defined simply as the “potential to perform work”. In that sense, of course, energy is not conserved; this is why the notion of “energy *consumption*” has become common usage.

The connection between the, at first, entirely different concepts of “energy” and “heat” was clarified only in the 19th century, with the formulation of the First Law of Thermodynamics stating that energy is preserved, i.e. it is neither created nor destroyed but just transformed from one form into another. (At the beginning of the 20th century, the concept of energy was extended by Einstein in his theory of special relativity, which includes mass as a form of energy.) Hence, energy consumption actually means energy *degradation* i.e. transforming valuable or available energy (exergy) into lower-value or non-available energy (anergy). The boundary between exergy and anergy is not absolute, but depends on the system considered. For instance, water at a temperature of 20°C in an environment at 0°C contains usable energy (exergy), while this would not be the case at an ambient temperature of 20°C.

The *energy system* (of a country or the Earth as a whole) is defined as the overall structure of the primary energy resources being used, the infrastructure for their distribution and transformation into final energy and the specific demand structure of so-called energy services. With regard to the quality of the energy, the distinction between the demand for heat or work plays, respectively a special role as well as the differentiation between stationary and mobile demand and the function of electricity. Together, the supply and demand structures determine the potential for changing an existing given energy system.

The term innovation describes a new problem solution prevailing in the market in connection with new factor combinations. Sustainable innovation means factor combinations and new problem solutions that lead to less environmental strain and a reduced consumption of resources without necessitating restrictions on other social objectives. An innovation does not have to be a new technological solution; it can also be a new service or a new form of organization.

In order to invigorate sustainable innovation one requires knowledge on innovation determinants. The extent, the direction and the speed of innovation activity in a national economy depend on a multitude of factors which are sometimes summarized as the “national innovation system”; these reach far beyond research and developments politics, touching on tax and education systems. In the course of European integration, it has become more appropriate in some areas to speak of a European innovation system. This entire context needs reshaping if innovation activity is to aim at a sparing use of resources. For policies concerning innovations a double strategy appears to be called for which, on the one hand, aims at short-term effects while, on the other, providing longer-term direction.

Through general improvements of the framework for sustainable innovation activity (e.g. regulation reform, tax reform, basic research priorities), the search efforts of scientists and inventors are steered into a different direction; the common pool of knowledge and ideas (the pool of inventions) is enriched accordingly. This part of the double strategy requires more time and has a general increase of sustainable innovation activity as its objective, rather than sector-specific potentials or specific types of innovation.

These components complement each other. Successful innovation policies emerge from the well-adjusted combination of both. As the transitions between the two kinds of innovation policies are fluid, arguments (partly shaped by ideology) about which one to choose will be unfruitful. Sustainable innovation policies as a whole have the objective to change the framework in such a way that the chances of sustainable innovation potentials to prevail in the market are improved. The advance of the framework for sustainable innovations finds itself confronted with the problem that successes are the result of long-term developments and cannot be causally attributed to certain changes of individual conditions. Hence, the political acceptance of reform especially of this kind is difficult to achieve.

From the factors of success and the obstacles thus identified, political recommendations can now be derived, where – after the acknowledgement of the principal need for innovation policies by the state – the choice of the concrete technology, the instruments, their dosage and the phase specifics are the main concerns. The recommendation emerging is a well-dosed combination of sponsorship for research far from the market (fundamental research), a search and discover function through competition followed by support for an accelerated diffusion and a general improvement of the conditions for sustainable innovation activity.

Normative evaluation and decision criteria

The application of traditional rules of decision-making requires a precise formulation of the relevant options for action and the environmental conditions influencing the effects of the action. However, for those cases where it is not clear which environmental conditions must be taken into consideration (decisions under profound uncertainty), these rules cannot be applied. Since long-term environmental transformations are characterized by profound uncertainty, different techniques of decision making have to be applied.

In such cases environmental politics calls upon the "precautionary principle" according to which preventive measures are permitted even if the scientific evidence is not conclusive, but merely plausible. The costs of such measures must be proportional (principle of proportionality), preferably, due to the profound uncertainty involved, in comparison to another end that is easier to specify. Precautionary measures with regard to climate change, for instance, can be assessed through the ends of secure supplies and a reliable energy system.

A set of ends for a sustainable reorganization of the energy system is listed in the following table:

Aim dimension	*Concretization*
Availability of resources	Period of secure practice
Energy system	Reliability (end user), openness of options, risk avoidance
Environment	Climate change, emissions, surface consumption

Whenever in this study we point out the necessity of a sustainable restructuring of the energy system, one has to keep in mind all of the ends cited above. However, for this set of ends the reduction of CO_2 emissions can serve as a "guiding indicator" that is supplemented by further indicators (surface consumption, openness of options etc.) in a particular context.

Every concept of sustainability involves certain normative decisions with specific ethical implications. The position that there is no such thing as an obligation towards future generations is – as far as we can see – hardly ever advocated as such. However, it does come out in the argument that the interests of future generations can be taken into account of today only insofar as the present generation is not harmed (intertemporal pareto-improvements). This "win-win" concept may suit innovations, because the accumulation of technological and organizational knowledge may compensate future generations for the diminished resources that will be at their disposition.

However, the obvious problem with this position is that as soon as the margins for pareto-improvements close in and an actual trade-off situation and hence a grave ethical conflict arises, conclusions become impossible. Therefore, employing an intertemporal pareto criterion can only be a first, largely ethics-abstinent step towards answering the questions we are concerned with. Are intertemporal pareto-improvements not possible in a particular case, one must look for justifications for the trade-offs (balances) between different options.

The question whether issues of intergenerational distribution – which are pertinent to the debate on sustainability – offer any leeway for pareto-improvements, as in the case of the sustainable energy innovations discussed in this paper, or if we face a trade-off situation at least in some areas, is of course an empirical one which has to be answered for every individual case.

However, any conception of sustainability introduces some type of intertemporal stock. The demand to conserve it – or the assumption that this would be fair – puts the concept of sustainability into a normative context.

Long-term responsibility is a fundamental aspect of the concept of sustainable development which can be – apart from its form in detail –

assumed unproblematic through recourse to a robust, moral intuition. Everybody will accept long-term obligations at least towards the generations immediately subsequent. There will also be an intuitive acceptance of the binding character of this obligation fading with the distance in time (*gradation*), for one will rather afford one's children a certain advantage or spare them some harm than one's descendents in the tenth generation. This gradation of the binding character can also be justified by the increasing uncertainty of the occurrence of the desired effects of action.

A notion of intergenerational justice is woven into the concept of critical sustainability, in the sense that the standards regarded as critical shall be adhered to. The concept of critical sustainability recurs to issues of gradation, most importantly in terms of the uncertainty of the relevant knowledge as discussed above.

Naturally, we cannot take into account future generations and their needs *correctly*, since these do not exist yet. For precisely this reason, we often see a distortion of the balance between ecological, social and economic criteria within the concept of sustainability: While the advocates of social and economic aspects rely on special interest groups, ecological aspects are only supported by environmental groups or agencies. The latter consist of members of the generations living today, but acting in favor of the supposed interests of future generations. At this point, science comes into play, for science cannot speak as an advocate for future generations. However, it should help to make transparent the risks of overstretching ecological resources by using the best scientific results available. Therefore we have to describe risks and future developments with uncertain effects, instead of providing simple "recipes" made up from clear facts.

Towards a sustainable energy system – deficits and points of reference

The idea of *sustainability as a legal standard* is relatively new. It was first taken up in the realms of international law. In the documents that emerged from the "Earth Summit" in Rio de Janeiro in 1992, this notion is found especially in Agenda 21. It was made legally binding somewhat later through specific treaties, namely the *United Nations Framework Convention on Climate Change*, which came into force following its ratification by 160 countries and was concretized in the *Kyoto Protocol* of 1997. The difference of interests between developed countries and developing countries as well as the diverging ideas about the relative weight of economic and ecologic interests in the industrialized countries have stripped this agreement of most of its effectiveness over recent years.

On the European level, since the Amsterdam renegotiations and already in the preamble of the original EU treaty, sustainable development is cited as one of the objectives. In the German constitution (*Grundgesetz*) (Art. 20a), "protecting the natural foundations of life" is laid down also with regard to the responsibility towards future generations.

However, the sustainability of the energy system must not be analyzed exclusively from the aspect of climate protection. At the foundation of the International Energy Agency (IEA) following the oil crisis of 1973/74, the *security of supply* (procurement) was the principal consideration. Today, about 50% of the energy demands of the European Union are covered by imports. In geopolitical terms ca. 45% of the oil imports origin from the Middle East; 40% of the natural gas imports stem from Russia. By 2020 – according to a EU prognosis – the import component will have risen to 70% again; over the same period we will see a shift to a renewed dependence on the Middle East, where about two thirds of future oil reserves are located and where, as estimated by the IEA, more than 85% of any additional production capacity is likely to be found.

Presently, neither the international nor the national legal standards are precise enough to derive direct, operative "sustainability targets" from them. However, effective political action requires precisely formulated objectives and the corresponding knowledge on action, both of which can only be developed in dialogue with the sciences. In particular, the sciences have to *analyze* the present energy systems and to formulate a precise *benchmark* for a sustainable provision of energy. The cornerstones of this analysis are the assertions that (1) commercial energy consumption has risen by a factor of 5 over the last 50 years, (2) more than 90% of this energy stems from fossil resources and (3) differences between the poorest and the richest countries, concerning the availability of commercial energy, are more than hundredfold. Most prognoses predict that the global energy demand will double or even grow by the factor of four until 2050. In contrast, for reasons of climate protection and supply security the consumption of fossil energy should be cut by half over the same period.

Two recepies are usually invoked to close the gap between demand and critical limits: *enhancing energy efficiency* and *decarbonization*. The first aims at decoupling the gross domestic product (GDP) from the energy demand, the latter at the substitution of fossil resources by renewable or carbon-free energy sources. The present development of the global energy system shows that both processes are far too slow to stop the growth of CO_2 emissions, let alone to reduce them. In other words, the present development of the global energy system is not sustainable, neither with regard to climate protection nor from the perspective of energy supply security, especially if the geographic distribution of the fossil energy resources is taken into account.

The essence of the above considerations can be summarized by the following simple calculation: Taking into account the typical growth target of the GDP of 2% for the EU and other industrialized countries and assuming a target of 2% for the reduction of the CO_2 emissions, we need a decrease of the CO_2 intensity (CO_2 emissions per GDP) of 4% per year. The CO_2 intensity is used as a guiding indicator for a sustainable transformation of the energy system.

In the following evaluation, the scenario "S450" of the Intergovernmental Panel on Climate Change (IPCC), which appears to be ambitious without being unrealistic, plays a central role. In addition, long-term trends, the need for political stability in the north-south relationship as well as a reduction of the dependence from Middle East oil are also important goals. To underline the last point we mention that at present the largest consumer of oil, the US, imports about 40% of its oil demand.

In order to operationalize the sustainability targets, two concepts are introduced: (1) The *time of safe practice* is based on the idea to characterize societal activities by the (hypothetical) time during which that activity could be carried on until it reached its limits (e.g. because of resource limitations, environmental strain etc.). (2) The *inertness* of the energy system can be defined as the time needed for a significant change of the system. For the present energy system, such a significant change could result in, for instance, the complete substitution of the present fossil energy supply by renewable energy resources.

With the help of these concepts, the aim of sustainability can be defined as follows:

(1) *A practice (e. g. an energy practice) is sustainable if the time of safe practice is constant or growing (principle of the constant time of safe practice).*

(2) *The time of safe practice must exceed the inertness of the system concerned.*

Applied to energy, this means that a sustainable energy system has to be supported by two pillars: (1) the efficient use of energy and (2) a growing use of solar and other renewable resources. With the technologies known today, the present standard of living in the EU could be maintained with an energy consumption of *2,000 Watt per person*. (The present demand in the industrialized countries amounts to between 4,000 and 10,000 Watt per person). This demand could be met in a sustainable manner, i.e. largely by renewable resources. The *2,000-Watt benchmark* forms the basis for our further considerations. We have reasons to assume that there is enough time for such a transition, provided that the process is vigorously initiated now.

Potentials and barriers for a sustainable energy system

The potential of innovations in the energy sector presently in development or recently introduced to the market is fundamental for such a transition. Hence, their assessment at different stages of development or at the early stages of commercial exploitation is the next step of the investigation towards a sound evaluation of their potential concerning energy efficiency.

There have been periods in the past – for instance periods of high energy prices – when the energy efficiency of new appliances improved by at least 5% annually. Now we pose the question if such an improvement can be achieved in the future too. By citing representative examples (energy consumption for residential heating, cars, electricity production and selected industrial processes), we show that the technical means are actually in place for realizing an annual improvement of upwards of 5% in the future. Already today, we are even able to specify precisely the potential for the coming, say, 15 years.

An improvement of the energy efficiency of new appliances of (annually) about 5% makes possible to halve – compared to the present situation – the total demand for energy by the year 2050. This calculation takes into account further economic growth and a slow turnover of capital stocks. Such a reduction in the energy demand is a precondition for a decisive growth of the relative contribution of renewable energies.

The present contribution of renewable energies in the energy market exceeds the general expectation of 20 years ago by a considerable margin. Wind energy will become commercially viable over the coming years. Photovoltaic energy still has a long way to go before achieving that goal. The wide spectrum of applications of biomass through a variety of technologies will become viable on a timescale somewhere in between. Short-term applications include its burning large power plants and its fermentation in small plants. A plethora of new technologies based on gasification for producing gaseous (for instance for the combined production of heat and electricity) and liquid fuels (e.g. for the transport sector) offer promising prospects.

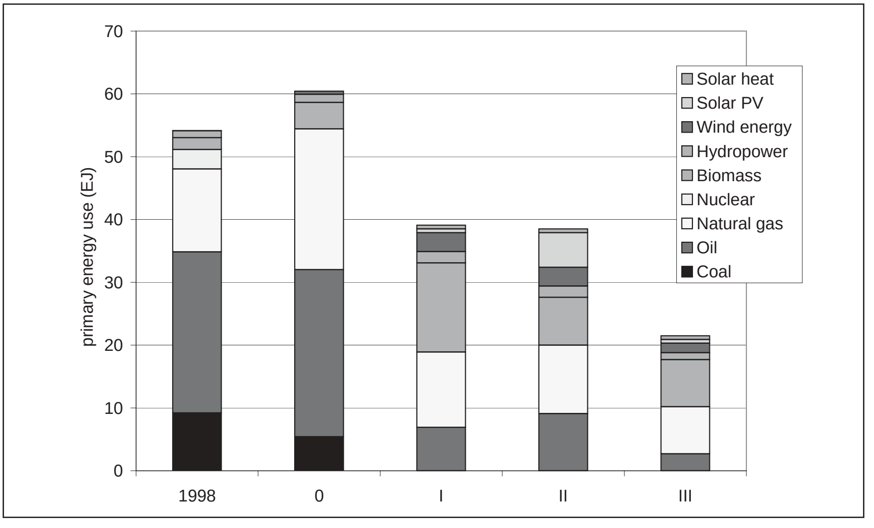
Taking into account the different types of renewable energy sources, we developed different scenarios for meeting at least half of the energy demand by using renewable energy sources.

0. The reference case: Continuing existing trends such as a slow improvement of energy efficiency, a gradual rise in the final-energy demand, an increasing contribution from natural gas, the phasing out of nuclear energy and small contributions from regenerative energy sources

I. A scenario involving the energy demand being relatively stable (albeit with a demand shift from heat to electricity) and a supply system based on the – under the condition of limiting the CO_2 emissions – cheapest abundant energy sources i.e. biomass and natural gas

II. The same demand development, but less use of biomass

III. A scenario with a markedly lower energy demand



At present hydropower is still the predominant renewable source for electricity production. For the coming decades, the largest growth is expected in the areas of wind energy and biomass. The prospects for biomass are most favorable, though the surface demand involved will be enormous. Still, even within the densely populated European Union, an extension of biomass exploitation sufficient for the biomass intensive scenario above (scenario I) is possible. Photovoltaic energy can only become important in the longer term. It is conceivable for this source to play a major role, but that would require extensive development efforts and cause higher costs.

Hence, there are several combinations of energy efficiency improvements and renewable energy sources that can reduce the demand for fossil energy in the European Union by 60 to 80%, compared to the present status, by the year 2050.

The developments lined out here will never happen without targeted measures. There are various obstacles to overcome. In many sectors energy does not represent an important cost factor. This is definitely true for the service and agricultural sectors. Even in residential households the energy costs are spread over several areas (mobility, heating, electricity etc.). Therefore the energy costs are often not considered appropriately when making decisions. Furthermore, the positive external effects (e.g. fewer emissions) are not appreciated properly in the market. New technologies reside at the upper end of the learning curve and cannot compete easily with established technologies, which have been optimized over a long period of use. On the other hand, the advantages of mass production are crucial if energy efficiency and renewable energies – especially if one deals with manufactured technologies – are to be competitive against established on-site technologies. In many cases, new technologies have to be compatible with existing plants and comply with existing standards and infrastructures, which again delays market penetration. This applies especially to a capital-intensive sector where "sunk costs" prevent a rapid turnover of capital.

Apart from that, the history of substituting one energy source by another shows that new energy sources must be not just competitive, they also have to offer additional advantages (for instance the "cleanness" of oil compared to coal). The substitution process is never untouched by politics (in every direction) and it strongly depends on the service life of the existing energy infrastructure. However, as soon as new technologies have acquired a critical mass, the substitution accelerates.

The reality of sustainability: Conflicts of aims in the choice of instruments

The promotion of "welfare" or the "public weal" is often cited as the purpose of political or ecopolitical action. However, the meaning of this is often unclear when one deals with concrete measures. The reason is that certain measures appear advantageous in some respect while, at the same time, they often imply drawbacks too. Such drawbacks can be the uneven distribution of the costs and benefits of a measure or that the removal of one problem implies the creation of a new one.

A well-known example is the magic quadrangle in macroeconomic policy: According to the law of stability and growth, a high level of employment, low inflation, external trade balance and appropriate growth have to be the objectives. However, in fact policies also aim at a fair distribution. These are five *aims of economic policy* with the effect that measures for improving the achievement of one aim can easily compromise the realization of one or several other aims. If, for example, a higher level of employment is achieved, this can create a risk of higher inflation and more imports, and possibly leads to lower achievement concerning two of the aims, namely “low inflation” and “trade balance”. If one aims to achieve a fairer distribution the wage rises, this can lead to less employment and growth. Again, two aims are met less successfully, if one promotes another aim. Hence we are dealing with *conflicts of* aims.

For this study, the conflicts between environmental aims and other ones are of particular importance. We discuss conflicts rooted in market shortcomings and distribution problems, where employment, competition, trade, finance and development policies are relevant. A reduction of environmental emissions, especially in the energy sector, requires the fall in production and thus either in employment or in wages, if employment levels are to be maintained.

If cost increases due to environmental policy measures cause a fall in production volumes on the factory level, the result is the same as that of monopolist action, where the monopolist sets a monopoly price. Thus, such measures can intensify monopoly effects, if they do not consider them properly right from the beginning.

A large part of energy emissions stems from (international) transport. (International) trade serves to enable the consumer or enterprises to buy goods at more favorable prices. If transport costs rise for environmental reasons, so that the environmental costs are borne by the polluter, this runs against the interests of transporters, importers and receivers of goods.

The weakness of environmental policies limited by national or regional boundaries lies in the fact that enterprises can migrate to other regions where they do not have to bear environmental costs. Empirically, this effect may well be minor because international competitiveness was given precedence, often through exemptions from regulations. However, in the absence of such exemptions, the effect partially leads to a deteriorating of employment levels and subverts the environmental policy itself, for instance because emissions then come in from less regulated countries.

To make the costs of environmental policies efficient, one is looking for ways to employ funds from industrialized countries in developing countries, if a stronger effect can be achieved there. If this leads to a stronger demand for land, for instance to realize reforesting programs within the framework of the *Clean Development Mechanism* (CDM) agreed in the Kyoto Protocol, it can mean higher rents asked from small tenant farms and higher food prices, which is in obvious conflict with the development aim of reducing poverty.

Conflicts of aims, as long as they exist, can forestall political decisions, because individuals, especially politicians and lobbyists, can differ in their judgement of the importance of different aims. In particular, they can differ in their acceptance (or non-acceptance) of the actual existence of a problem or in their assessment of the extent of a problem. It can be very expensive in the long term, when no measures are taken because there is insufficient information even if a relevant problem is indeed very important or when measures are decided which later turn out to be unnecessary.

Consequently, the conflict-laden distribution effects of environmental efficiency gains have to be defused in order to reduce resistance. This can be achieved through innovation-political measures. The promotion of superior technologies – in terms of their environmental effects – can cut the marginal costs of enterprises, increase employment and reduce monopoly prices as well as transport emissions without hampering international trade or causing capital migration. Such technology support takes place at home, not in developing countries. The import of superior technologies only reduces emissions if these technologies become the standard and older technologies disappear from the market. To that extent, the contrasting interests outlined above are absent in the employment of innovation policies. Innovation policies can be used as a complement to other environmental measures. In order to gain approval for measures such as environment taxes and certificates, one can offer innovation incentives softening the effects of the cost distribution.

Within the legal framework of the European Union, rules have emerged on what must be considered when economic aims – for instance the free movement of goods and services in the internal market – are put aside in favor of the protection of the environment. The reasons must be compelling and the instruments used must affect the internal markets as little as possible. The rules often require only a temporary intervention or the setting of threshold values (e.g. in the case of subsidies for environmental protection technologies). The European Court of Justice has laid down strict rules concerning the corresponding evidence required.

Conflicts with EU competition laws can arise in two respects. State incentives have to be measured against the prohibition of subsidies which covers all national incentive measures favoring the recipient financially, but, in the view of the European Court, does not affect the rules concerning purchase volumes and compensation duties which mainly present a financial burden for private-sector energy suppliers and lead only indirectly, if at all, to national revenue losses. Any existing subsidy can be justified on environmental reasons, if it is in accordance with the common framework for state subsidies in the environmental sector. This framework provides special rules for regenerative energies, allowing, in principle, at least temporary subsidies. The polluter-pays principle which dominates the common subsidies framework too, gives reason for concern.

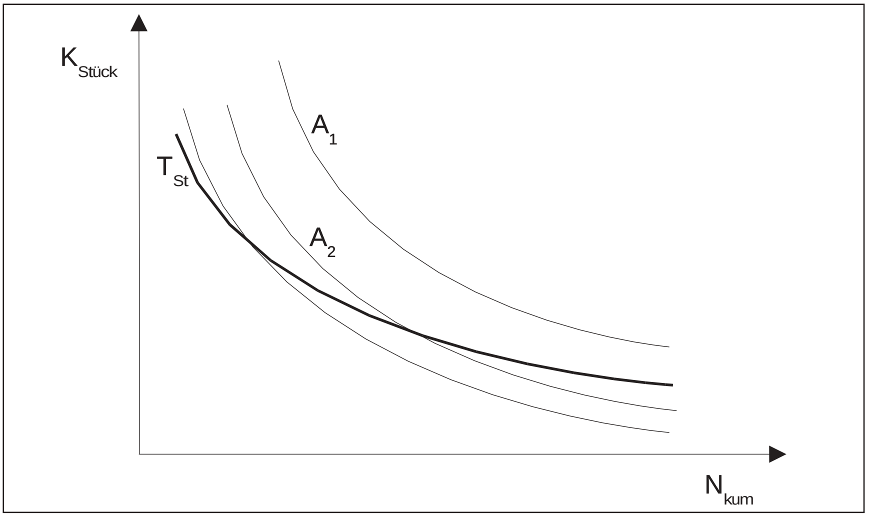
The second source of conflict in terms of competition law exists in the competition rules governing enterprises. Where self-regulation within the private sector, e.g. concerning CO_2 reduction or regenerative energies, leads to cooperation between companies and thus affects free competition, this too can be justified, if it is inalienable on reasons of environmental protection. Insofar as it offers the prospect of similar effects as state support measures or market interventions, such self-regulation can also put in question the necessity of restrictions to the movement of goods.

Strategies to accelerate energy innovations

A strategy has to activate the potentials with regard to the 2,000-Watt benchmark without failing at the obstacle of conflicting aims, i.e. the balancing of the three pillars of sustainability. The analysis above allows developing such a strategy with a bundle of measures to promote sustainable energy innovations:

1. We propose a strategy to accelerate sustainable energy innovations through custom-made support measures for different phases of their life cycle within a learning curve model. At the beginning of the life cycle, subsidies should help achieving the cost advantages of the effects of scale by enabling enterprises to move faster along the "learning curve" of cost reductions. In a later phase, measures of self-regulation as negotiated solutions or as unilateral self-commitments of the private sector should lead to a faster penetration of the market.

   The focus is on energy-efficient technologies at the stage of their market introduction, meaning that pilot projects and demonstration proposals already exist and the technology concerned is now at a stage where an "early adapter" has to be found and industrial production and service structures to be developed through higher quantities. In the majori-



Learning curves for energy-efficient technologies compared to the standard technology (T_{St}). ($K_{Stück}$: Unit costs, N_{kum}: accumulated production volume) ty of cases, these subsidies take the shape of start-up financing. For it can be shown that, in most cases, the costs of the clean technology do not exceed those of the old technology in the long run (see curves A2 and A3 in the graph below). In the face of energy markets characterized by deregulation and volatile prices, such support is particularly important for regenerative energy sources. The different technologies do not all start from the same situation. Energy production from wind power is much closer to profitability than photovoltaic energy. Energy from biomass could turn out too expensive in the industrialized countries of the northern hemisphere, but not in developing tropical countries. Therefore, the promotion of various technologies must be customized depending on their position on the learning curve and the answer to the question, how soon can they profit from economies of scale. For the decentralized, "manufactured" technology of energy production from regenerative sources, the efficient mass production is the most certain way to compete with "on-site" technologies such as power.

For this approach to subsidies, the Dutch model of the "energy list" is referred to specifically. By maintaining a list of technologies eligible for support, which is updated annually, one avoids subsidizing a technology for a longer period than necessary. The experience gained in the Netherlands – experience with overcoming information asymmetries, minimizing free-rider effects and focusing exclusively on technologies that are in fact innovative – have to be taken into consideration.

2. Demand should be further stimulated through state procurement programs. For instance, in the course of regular construction, modernizing and repair measures over the next 5–7 years, one in three new public buildings could have a photovoltaic energy plant installed.

3. The extension of basic research into energy technologies, from nuclear fusion to solar energy, is imperative in order to ensure a continuous flow of new knowledge. This is clearly a task where government action is required. A reduction in the funds made available for such research (6. EU Framework Program for research, technological development and demonstration [2002–2006]) is definitely not the right approach.

4. Beyond that, governments should engage in the areas of appropriate education and infrastructural creation of competence for new energy technologies.

5. The total energy consumption in residential households and in connection with mobility is still rising. There is a number of approaches available to influence the present negligence of consumers concerning energy consumption. The instruments of regulating households as main origin of energy consumption, emissions and waste are far less developed than in the industrial domain (e.g. the IPPC directive stipulating the use of the “best available technology”).

   Consumers are not only restrained by the lemming effect but also by information deficiencies preventing them from making sound decisions. Therefore, we recommend effective and credible labeling including the “greenpricing” of electricity from regenerative sources. The poor success of previous approaches can be explained by the overflooding of the market with labels, leading to the failure even of official labels to clarify sufficiently the difference between sustainable and non-sustainable products. In some cases, this was a result of industry lobbying, in others it was caused by a lack of practical differentiation criteria.

6. More promising could be to bank on social and organizational innovation in order to accelerate the diffusion of energy innovations in residential households. An example of such innovation is the experiment of supply companies – often partnered by public institutions and enterprises – to position themselves as service providers. Such a step frees them from the pressure to sell more and more energy. Instead, they can offer profitable services for the efficient use of energy.

7. In the transport area, more energy-efficient providers have to build more comfortable and faster logistics or mobility chains, compared to private and commercial motor vehicles. Higher market shares cannot be achieved by improving the individual components, but only by revising the entire transport process. This requires innovative packages, for instance the link-up of rail traffic with car sharing and information services.

8. Still, in this case too, only looking at technology development is not enough. At least equally important is the compatibility with existing infrastructures and processes as well as the integration with the electricity network, both on the local level (for compensating discontinuous resources such as wind) and in the European arena (for instance by channeling hydropower produced in Scandinavia to the South during winter and using photovoltaic energy from Italy in the North during the summer months). For fuel cells, overcoming the "chicken and egg" problem (no vehicles without hydrogen distribution, no hydrogen market without vehicles) is a crucial precondition for the success of this promising technology. However, its true advantages, with regard to CO_2 intensity, will only emerge when hydrogen will be produced from regenerative energy sources.
9. Energy issues must regain the highest political priority.
10. Beyond that, we call for the foundation of an "alliance for sustainable energy innovations" organized as a network.

Political enforceability of sustainable energy innovations

This study is not limited to the development of options for action; it also examines their political enforceability. We explicitly look at the interests of different social groups of agents (politicians, consumers, companies, environmental organizations etc.), where we will touch on three aspects in particular: the aims level, the choice of instruments and the strategy for enforcement.

Sustainable innovation in the energy sector lead, as a whole, to the long-term growth of social wealth; however, at the same time it requires transformations in the social aims system as well as reforms that appear less attractive, at least in the short term, to some social groups (including essential parts of the energy industry). Given the interests of the groups of agents, we cannot expect the spontaneous emergence of a broad coalition for action concerning sustainable innovation in the energy sector. Each such group (enterprises, consumers etc.), on the other hand, disposes of a certain scope for action towards sustainable innovation, which they can realize without having to give up their principal interests. If we succeeded in exploiting this scope consistently, we could create a dynamics of reform that could take us beyond the status quo (which is not conducive to sustainability). The question how to initialize and organize this process remains.

Concerning the choice of instruments, one has to examine the enforceability of the instrument mix invigorating sustainable innovation in the energy sector at the lowest possible social costs. In the political process, economically efficient instruments stimulating innovation, such as certificate solutions or eco-taxes for environmental protection, have turned out be less attractive.

The instrument mix proposed here has a better chance of enforceability. It calls upon subsidy solutions, self-regulation and information instruments (labels etc.), because these do not imply immediate, perceivable strains on well-organized groups of agents. Hence, in the short term, sustainable innovation policies must make use of the potential of these instruments in particular.

Innovation-guided policy will have to face resistance, too, but not as much as allocative policies based on taxes, regulation or certificates. The promotion of sustainability policies requires a clearly defined process for formulating binding targets and for ensuring maximum engagement and the creation of capacities towards a platform, on which groups (even if they support opposite positions) can learn (to improve) co-operation, exchange experiences, report on their learning successes and become an integral part of a global network with a shared vision of the future.

New institutions are usually treated with skepticism. In contrast to specialized authorities, from central banks to antitrust regulators, sustainability affects every aspect of life; it cannot be separated from the core of democratic politics. Nevertheless, our analysis has shown that it often suffices to link-up existing institutions in a network in order to integrate the concept of sustainable development into their particular competences.

We therefore propose the foundation of an “alliance for sustainable energy innovations”, which should focus on three objectives:

- Increasing the public awareness of the divergence between energy demand and growth limitations and the potential of sustainable energy innovations for "pushing out the boundaries" if this potential is exploited more urgently,

- identifying obstacles (e.g. inefficiencies) to an accelerated realization of sustainable energy innovations and the promotion of new solutions, and
- building a database and a center for the transfer of knowledge on sustainable energy innovations for an easy access to every information on specific energy innovations, partners for co-operations, consultancies etc.

The members of such an alliance could be:

- Enterprises and industry federations (e.g. producers of solar and "conventional" energy, energy customers),
- scientific research institutions,
- energy agencies and institutions for technology transfer, and
- consulting and service companies with innovative, creative ideas.

The more members the network includes, the more valuable will it be for the individual member. Ultimately, the alliance could cultivate contacts beyond Europe, especially with developing countries, where the real struggle for a sustainable energy system is fought.

Responsibility for the "energy hunger" of the developing countries – How can sustainable energy innovations help here?

The measures proposed here may be judged on a global scale, but the measures themselves largely focus on the EU. However, we would not meet the criterion of intergenerational justice if we failed to examine to what extent sustainable energy innovations could level recognizable "north-south slopes".

The principal features (characterizing the situation in the southern hemisphere) concern the dearth of competence and infrastructure, the limited commercial supply of energy and the inefficient use of energy sources, especially fire wood. Many modern technologies for energy production from regenerative sources – from wind power, biomass and solar radiation, in particular – ought to be employed in those countries. However, before such technologies can gain practical relevance, competences and infrastructures have to be built. In the sparsely populated rural areas outside the towns, decentralized technologies are often much more useful than centralized provision. In this field too, far-reaching targeted measures are necessary.

A multitude of international organizations – primarily the World Bank and the Global Environmental Facility (GEF) – endeavor to support sustainable energy systems and innovations in developing countries. The EU, on the other hand, suffers a particularly low profile in this area: Energy does not play a significant role, not even an institutional one. This has to change and there have already been various good proposals (e.g. the G8 Task Force, whose well thought-out suggestions were, unfortunately, rejected).

Apart from that, the number of successful examples show that global enterprises play a much more active role in technology sharing, for instance through direct investments (e.g. production plants for wind turbines). Obviously such enterprises would rather be guided by policies than venture independently on unknown territory. Therefore, the EU would have to make the effort of integrating energy issues and energy technologies with her development policies more closely than in the past. In this way, a framework and incentives for more investment in energy innovations and their development by the private sector would emerge.

However, development aid, technology transfer etc. will only become effective if the industrialized countries themselves manage successfully to transform their own energy systems. Hence, energy innovations in industrialized countries are a precondition for sustainable energy systems in developing countries. This realization takes us back to the starting point of our analysis: Even if the global dimension of the energy question is indisputable, most energy-relevant decisions are taken on national, communal or even individual levels. Therefore, to promote sustainable energy innovations, we need a long-term, international engagement by all agents on all those levels, from enterprises to nongovernmental organizations, from scientists to national administrations.

Previous Publications of the Graue Reihe:

1 Carl Friedrich Gethmann, Armin Grunwald, Technikfolgenabschätzung: Konzeptionen im Überblick, 9/96, 2. Aufl. 7/98

2 Carl Friedrich Gethmann, Umweltprobleme und globaler Wandel als Thema der Ethik in Deutschland, 9/96, 2. Aufl. 10/98

3 Armin Grunwald, Sozialverträgliche Technikgestaltung: Kritik des deskriptivistischen Verständnisses, 10/96

4 Technikfolgenbeurteilung der Erforschung und Entwicklung neuer Materialien. Perspektiven in der Verkehrstechnik. Endbericht zum Vorprojekt, Arbeitsgruppe Neue Materialien, 1/97

5 Mathias Gutmann, Peter Janich, Zur Wissenschaftstheorie der Genetik. Materialien zum Genbegriff, 4/97

6 Stephan Lingner, Carl Friedrich Gethmann, Klimavorhersage und -vorsorge, 7/97

7 Jan P. Beckmann, Xenotransplantation. Ethische Fragen und Probleme, 7/97

8 Michael Decker, Perspektiven der Robotik. Überlegungen zur Ersetzbarkeit des Menschen, 11/97

9 Carl Friedrich Gethmann, Nikolaj Plotnikov, Philosophie in Rußland. Tendenzen und Perspektiven, 5/98

10 Gerhard Banse (ed.), Technikfolgenbeurteilung in Ländern Mittel- und Osteuropas, 6/98

11 Mathias Gutmann, Wilhelm Barthlott (eds.), Biodiversitätsforschung in Deutschland. Potentiale und Perspektiven, 11/98, 2. Aufl. 4/00

12 Thorsten Galert, Biodiversität als Problem der Naturethik. Literaturreview und Bibliographie, 12/98

13 Gerhard Banse, Christian J. Langenbach (eds.), Geistiges Eigentum und Copyright im multimedialen Zeitalter. Positionen, Probleme, Perspektiven, 2/99

14 Karl-Michael Nigge, Materials Science in Europe, 3/99

15 Meinhard Schröder, Stephan Lingner (eds.), Modelling Climate Change and its Economic Consequences. A review, 6/99

16 Michael Decker (ed.), Robotik. Einführung in eine interdisziplinäre Diskussion, 9/99

17 Otto Ulrich, “Protection Profile” – Ein industriepolitischer Ansatz zur Förderung des “neuen Datenschutzes”, 11/99

18 Ulrich Müller-Herold, Martin Scheringer, Zur Umweltgefährdungsbewertung von Schadstoffen und Schadstoffkombinationen durch Reichweiten- und Persistenzanalyse, 12/99

19 Christian Streffer et al., Environmental Standards. Combined Exposures and their Effects on Human Beings and their Environment (Summary), 1/00

20 Felix Thiele (ed.), Genetische Diagnostik und Versicherungsschutz. Die Situation in Deutschland, 1/00, 2. Aufl. 2/01

21 Michael Weingarten, Entwicklung und Innovation, 4/00

22 Ramon Rosselló-Mora, Rudolf Amann, The Species Concepts in Prokaryotic Taxonomy, 8/00

23 Stephan Lingner, Erik Borg, Präventiver Bodenschutz. Problemdimensionen und normative Grundlagen, 9/00

24 Minou Bernadette Friele (ed.), Embryo Experimetation in Europe, 2/01

25 Felix Thiele (ed.), Tierschutz als Staatsziel? Naturwissenschaftliche, rechtliche und ethische Aspekte, 2/01

26 Vitaly G. Gorokhov, Technikphilosophie und Technikfolgenforschung in Russland, 2/01

27 Chris W. Backes, Klimaschutz in den Niederlanden, 3/01

28 G. Hanekamp, U. Steger (eds.), Nachhaltige Entwicklung und Innovation im Energiebereich, 7/01

29 Thomas Christaller, Michael Decker (eds.), Robotik. Perspektiven für menschliches Handeln in der zukünftigen Gesellschaft. Materialienband, 11/01

30 Selgelid, Michael, Societal Decision Making and the New Eugenics, 4/02

31 Irrgang, Bernhard, Humangenetik auf dem Weg in eine neue Eugenik von unten?; 2/02

32 Meinhard Schröder et al., Climate Prediction and Climate Precautions, 06/02