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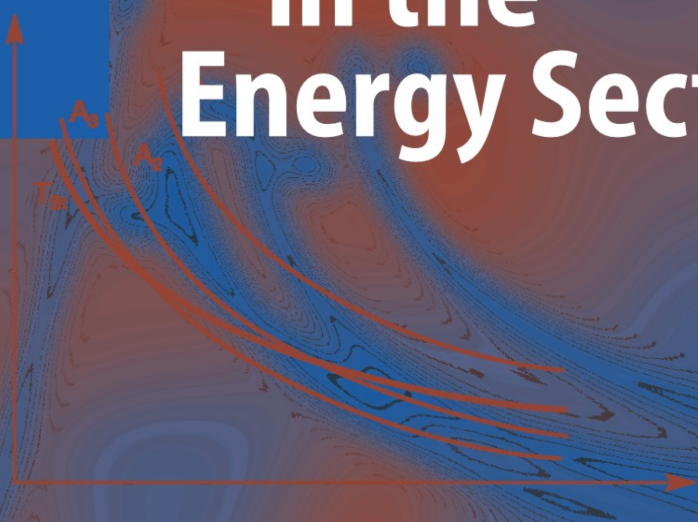

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With 33 Figures

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Preface to the Translation

The *Europäische Akademie zur Erforschung von Folgen wissenschaftlich-technischer Entwicklungen Bad Neuenahr-Ahrweiler GmbH* is concerned with the scientific study of the consequences of scientific and technological advance both for the individual and social life and for the natural environment. The Europäische Akademie intends to contribute to a rational way of society of dealing with the consequences of scientific and technological developments. This aim is mainly realised in the development of recommendations for options to act from the point of view of a long-term societal acceptance. The work of the Europäische Akademie mostly is carried out in temporary interdisciplinary project groups whose members are notable scientists from various European universities. Overarching issues, e.g. from the fields of Technology Assessment or Ethics of Science, are dealt with by the staff of the Europäische Akademie.

The results of the work of the Europäische Akademie is published in the series "Wissenschaftsethik and Technikfolgenbeurteilung" (Ethics of Science and Technology Assessment), Springer Verlag. The academy's study report 'Nachhaltige Entwicklung und Innovation im Energiebereich' was published in October 2002. It contains a straightforward strategy how innovations can help to achieve a sustainable development in the energy sector. The academy decided to provide for an English translation of this report that is published in the present volume in order to make this strategy available to a wider scope of recipients.

Bad Neuenahr-Ahrweiler, June 2004 Carl Friedrich Gethmann

Preface

In discussions concerning sustainable development, innovations are often cited as a "miracle cure". Through innovations, we are to prevent a situation where an increase in output leads to an increase in the consumption of natural resources. This means for the of energy sector: Innovations should help us to reconcile the further growth of the national products of the industrial countries, and at?? the backlog demand of the developing and emerging nations, with a reduction in the consumption of non-renewable energy resources, which must not give rise, however, to an inappropriate consumption of other resources.

The core question addressed by the interdisciplinary project group, "Sustainable development and innovation in the energy sector", which was established by the Europäische Akademie (european academy) in September 2000, was therefore: "To what extent can innovations lead to a sustainable energy system?" The members of the group were selected according to their competences within their disciplines with regard to the subject to be dealt with. The project time frame was 20 months, of which 13 days were spent in plenary session.

The final report presented here derives from chapters, which were drafted, under the direction of one of the group members, by individual working groups before being integrated by the plenum. The work of the project group was based on the judgment that "interdisciplinary research" does not exist as such, but disciplinary competences are a prerequisite for dealing with individual aspects of the subject. An integration of the various disciplinary perspectives, methodologies and results with regard to the non-disciplinary question at hand follows as the second step. The procedure pursued by the group was transdisciplinary, in this sense. The result is a text that is consistent in itself, and a coherent argumentation that can be examined step by step (even if the disciplinary background of the "original author" is easily detected in some sections of the report).

The group was open to continuous inspection by external specialists. The work schedule was discussed at the kick-off workshop in January 2001.

We thank our colleagues, Professor Dr. Wilhelm Althammer (Handelshochschule Leipzig), Professor Dr. Nicholas Ashford (MIT), Dr. Gerd Eisenbeiß (Forschungszentrum Jülich), Dr. Klaus Rennings (ZEW Mannheim), Dr. Herwig Unnerstall (Universität Leipzig), Professor Dr. Alfred Voß (Universität Stuttgart) and Professor Dr. C.-J. Winter (Energon) for their valuable suggestions and pointed criticism, which both helped to provide a precise orientation for this study. At the mid-term workshop in November 2001, a first draft was presented to the following colleagues: Professor Dr. Dr. Brigitte Falkenburg (Universität Dortmund), Professor Dr. Wilhelm Althammer (Handelshochschule Leipzig), Dr. Gerd Eisenbeiß (Forschungszentrum Jülich), PD Dr. Volker Radke (Berufsakademie Ravensburg), Dr. Klaus Rennings (ZEW, Mannheim) and Dr. Herwig Unnerstall (Umweltforschungszentrum Leipzig). We also extend our thanks to the participants of that meeting, for their meticulous comments, which later helped to round off the study. Thanks to a good working discipline, the materials on which the discussions were based were ready in time for almost every session. The intellectually stimulating working atmosphere, characterized by professional respect and friendly cooperation, allowed for intensive, constructive, at times controversial discussions and mutual learning throughout various perspectives and methods.

The group's productivity was fostered, not least, by the hospitality of the Ahr valley, and the friendly and efficient services, with which the Academy staff supported our work, especially Ms. Pauels, to whom we would like to express our gratitude. We also thank Mr. Jochen Markard and Mr. Joachim Schmidt-Bisewski, who accompanied the project through the early stages, as well as Ms. Sevim Kilic of the european academy, who worked on the text and prepared it for publication.

Lausanne, June 2002

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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.

So far, however, 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 competencies 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 on the other hand especially by ecological economics, the "science of sustainability". 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 degree Celsius in an environment at zero degree contains usable energy (exergy), while this would not be the case at an ambient temperature of 20 degree.

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, respectively, plays 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