Forschungszentrum Jülich

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Study on Behalf of the Federal Environmental Agency

edited by
G. Stein and B. Strobel

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from: J. Diekmann, R. Hopf, H.-J. Ziesing (DIW);
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Methodological Guideline for Assessing the Impact of Measures for Emission Mitigation

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Gotthard Stein and Bernd Strobel

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Key to Abbreviations

a	year
BAU	business as usual (status quo)
BDI	Bundesverband der Deutschen Industrie / Federation of German Industries
BGW	Bundesverband der deutschen Gas- und Wasserwirtschaft e.V. / Association of Gas and Water Industries
BMBF	Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie / Federal Ministry of Education, Science, Research and Technology
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit / Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMWi	Bundesministerium für Wirtschaft / Federal Ministry of Economics
BVWP	Bundesverkehrswegeplan / federal transport route plan
CO_2	carbon dioxide
d	days
DIW	Deutsches Institut für Wirtschaftsforschung / German Institute for Economic Research
DOE	Department of Energy (USA)
DtA	Deutsche Ausgleichsbank / German Equalization Bank
EFOM	Energy Flow Model (optimization model)
EIA	Energy Information Administration, DOE
ERP	Enterprise Resource Planning
EU	European Union
FCCC	Framework Convention on Climate Change
FhG	Fraunhofer-Gesellschaft / Fraunhofer Society
GEU	Gesellschaft für Energieanwendung und Umwelttechnik mbH, Leipzig / Energy Application and Environmental Technology Company
GJ	gigajoule

GWh	gigawatt hours
h	hours
HEL	heating oil, extra light
H_o	higher calorific alue
H_u	lower calorific value
IDEAS	Integrated Dynamic Energy Analysis (simulation model)
Ifo	Institut für Wirtschaftsforschung e.V., Munich / Institute for Economic Research
IKARUS	Instrumente für Klimagasreduktionsstrategien / Instruments for Greenhouse Gas Reduction Strategies (BMBF project)
IPCC	Intergovernmental Panel on Climate Change
ISI	Fraunhofer-Institut für Systemtechnik und Innovationsforschung / Fraunhofer Institute for Systems Engineering and Innovation Research
KfW	Kreditanstalt für Wiederaufbau / Reconstruction Loan Corporation
km	kilometre
kph	kilometres per hour
kW	kilowatt
kWh	kilowatt hour
LP	linear programming (optimization method)
MARKAL	market allocation (optimization model)
MW	megawatt
MWh	megawatt hours
MWV	Mineralölwirtschaftsverband / Association of Oil Industries
pkm	passenger kilometre
PJ	petajoule
STE	Programmgruppe Systemforschung und Technologische Entwicklung, Forschungszentrum Jülich / Programme Group Systems Analysis and Technology Evaluation, Research Centre Jülich
t	tonne
tkm	tonne kilometre

TFF	Programmgruppe Technologiefolgenforschung, Forschungszentrum Jülich / Programme Group Technology Assessment, Research Centre Jülich
TJ	terajoule
toe	tonne oil equivalent
VDEW	Vereinigung Deutscher Elektrizitätswerke / Association of German Power Stations
VEA	Bundesverband der Energieabnehmer e.V. / Federal Association of Electricity Consumers
VEAG	Vereinigte Energiewerke AG / Combined Energy Works
VIK	Verband der Industriellen Energie- und Kraftwirtschaft e.V. / Association of the Energy and Power Industry
VKU	Verband Kommunaler Unternehmen, Cologne / Association of Municipal Enterprises
W	watt
WSchV	Wärmeschutzverordnung / Heat Insulation Ordinance
ZVEI	Zentralverband Elektrotechnik- und Elektroindustrie, Frankfurt / Central Association of the Electrical Engineering Industry

Energy Units

SI prefixes

m	milli-	10^{-3}
k	kilo-	10^{3}
M	mega-	10^{6}
G	giga-	10^{9}
T	tera-	10^{12}
P	peta-	10^{15}
E	exa-	10^{18}

Energy and power units

J	joule	1 J = 1 Ws
W	watt	

Conversion factors

1 kcal	4.1868 kJ
1 kWh	3,600 kJ
1 kg hard coal equivalent	29,308 kJ
1 kg crude oil equivalent	41,868 kJ
1 m^3 natural gas	31,736 kJ

1 Introduction

In 1990 the German Federal Government set itself the goal of a 25% reduction of the emission of carbon dioxide in the year 2005 based on the 1990 level and has reaffirmed this goal many times. In past years, numerous policy measures for environmental protection have already been taken and additional measures are being planned or discussed at the moment. In order to evaluate national policy efforts for climate protection with respect to reaching this goal, the effects of previous and future measures must be quantified as reliably as possible.

Impact analyses of policy measures for climate protection are also part of the national obligation to make an annual report under the Framework Convention on Climate Change (FCCC). The corresponding guidelines of the FCCC "Policies and Measures" (Geneva, 17 July 1996) contain general criteria for the description of the measures and their effects, which are to be displayed in a sectorally differentiated manner. However, the concepts on which the classification of the measures and effects is based are in part not clearly defined. The question also remains of the methodological procedures with which the effects of the policy can be estimated with sufficient precision and to which of the individual measures they can be allocated.

Against this background, the Federal Environmental Agency (UBA) has, within the framework of its environmental research plan, charged the Research Centre Jülich with the implementation of a project "Policy Scenarios for Climate Protection". In this context, the findings and instruments from the IKARUS project[1], which is supported by the Federal Ministry of Education, Science, Research and Technology (BMBF), should be made available for reports by the Federal Government as well as strategy assessments as part of the FCCC. The comprehensive project was implemented by the German Institute for Economic Research (DIW), the Fraunhofer Institute for Systems and Innovation Research (FhG-ISI), the Programme Group Systems Analysis and Technology Evaluation of the Research Centre Jülich (STE) and the Institute of Applied Ecology

[1] In the IKARUS project, instruments have been developed with which strategies for the reduction of energy-related climate gas emissions can be investigated and optimized with regard to the techniques to be used according to certain criteria - minimization of the costs for predefined emissions. The instruments consist of energy-economy computer models as well as an extensive database.

(Öko-Institut) under the administrative coordination of the Programme Group Technology Assessment of the Research Centre Jülich (TFF).

The results of the project "Policy Scenarios for Climate Protection" have been published in two volumes (Ziesing et al. 1997, Schön et al. 1997). The present Volume 3 discusses methodological questions about the impact evaluation of measures for emission reduction. In this context, the goal is to formulate a generally comprehensible guideline for future analyses, taking into consideration past experience with the implementation of impact assessments. In this report, the methodological approaches used as well as the possibilities and limitations of a methodologically improved impact analysis are discussed.

Methods of impact analysis in climate protection are especially taken to mean those procedures that are suited for contributing to assessing the impacts of policy options for climate protection on energy consumption and thus on the emission of greenhouse gases[2]. On the one hand this is a matter of estimating the efficacy of the individual policy measures and on the other hand of quantifying the political success of climate protection in the policy scenarios in the sense of *qualified* forecasts.

A number of methodological problems arise with such impact analyses. For instance, as a rule, the impacts of individual measures can hardly be isolated empirically from other effective factors and in part the impacts of measures have to be estimated for which there is no past experience. Moreover, there are substitutive or complementary impact relations between the individual measures, so that combinations of measures cannot be rated as the sum of the single effects. In addition, the political measures to be analysed are only partially of a qualitative nature and policy impacts, especially in the case of an indirect influence of the energy use, can basically only be quantified under certain hypotheses. Purely technological analyses are therefore just as inadequate as purely economic analyses. With regard above all to the reaction of energy consumers to policy measures for climate protection, findings of sociological behaviour models are also to be taken into consideration.

[2] Neither effects on the national economy nor climate effects were the subject of the investigation. The estimates of effects on energy consumption and emissions dealt with in this text, are, however, a fundamental precondition for such continuous analyses, including in particular also the integrated analyses of climate protection.

The study under review is structured as follows. First of all, in *Chapter 2* the general methodological basis of the impact evaluation of measures for emission reduction is dealt with. The goals and problems of the impact analyses of policy measures are explained, an international summary of approaches - especially on the basis of national reports according to the FCCC - is given, as well as a discussion of the possibilities and limitations of formal models. *Chapter 3* introduces a combined approach for deriving policy scenarios for climate protection, which is, on the one hand, founded on model-based, technology-oriented optimizations and, on the other hand, on policy-oriented expert judgements. After a short survey, the scenario concepts to be investigated (*"without measures", "with measures", "with additional measures"*)are explained. The chapter describes how the linear optimization model developed in the IKARUS project can be used within this context to derive the fields of action and how the impact of the individual measures and bundles of measures can be quantified within the framework of expert judgements. Due to sector-specific, impact-related mechanisms and an uneven data availability - assuming a general study approach - a sectoral procedure is appropriate. The sectoral results are then to be converted into strategic policy scenarios in an additional step. The most important methodological conclusions are summarized in *Chapter 4*.

The discussion about the methodological aspects of the impact assessment of measures for emission reduction is focused on past application experience for Germany. In other countries, it is quite possible that, depending on political, economic and social circumstances, as well as the analysis instruments and data basis available, new paths are being successfully trod.

This subproject - as well the overall study - has been carried out by a division of labour under the supervision of the DIW. The drafts of the individual chapters were prepared by the following division of efforts: Chapter 1: DIW, Chapter 2: DIW, TFF (2.2), Chapter 3: DIW, ISI (3.4.3), STE (3.3, 3.4.4.1), Öko-Institut (3.4,4.2), Chapter 4: DIW, ISI, TFF.

2 General Methodological Principles

2.1 Objectives and Problems of Impact Analysis

2.1.1 Preliminary Remarks

The National Reports available to date as part of the Framework Convention on Climate Change (FCCC) differ very greatly both with respect to the measures discussed for climate protection as well as methods for assessing their impacts on emissions of greenhouse gases (cf. Section 2.2 and Kunz, Holtrup 1997).

The *First National Report* by the Federal Republic of Germany (BMU - Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 1994) comprises, in addition to a representation of the initial situation, in particular a formulation of the Federal Government's objectives and a catalogue of approved and planned policy measures. In order to quantify the future development of emissions in Germany, various forecasts and scenarios are quoted in the first country case study considering some of the measures already effective or initiated, but not the entire catalogue of measures.

However, the Federal Government does not "adopt any statement from these forecasts, although it takes these findings into consideration in drawing up its policy" (BMU 1994, p. 130). According to the Federal Government, the validity of forecasts and scenarios is generally restricted by the fact that they can always only be regarded as qualified predictions. Unpredictable events can naturally not be included. Furthermore, the Federal Government draws attention to the methodological limits of an assessment of the future impacts of policy measures: "A further reason for the relativity of forecasts and scenarios on energy consumption and the development of greenhouse gas emissions is the plain and simple fact that the future effects of certain measures cannot be estimated even with the most methodologically sophisticated instruments" (ibid.). Examples are given such as the amendment to the Energy Management Act, the revision of the scale of fees for architects and engineers, and measures for advisory services, information, education and further training. It must furthermore be noted "that interdependences between the individual measures lead to the sum being as a rule greater than simply adding up the impacts of individual elements" (ibid.). On the other hand, adding up the isolated estimates of the impacts of measures may also lead to considerable double counts which have to be avoided.

The Federal Government's position outlined here displays, on the one hand, regulatory reservations concerning detailed future scenarios and, on the other hand, underscores the special methodological difficulties which may be associated with the impact analysis of policy measures. However, in its *Second National Report* as part of the Framework Convention on Climate Change (BMU 1997) the Federal Government specifies estimates of the CO_2-mitigating effects for a number of measures already taken largely based on findings by Ziesing et al. (1997) and Hillebrand et al. (1996).

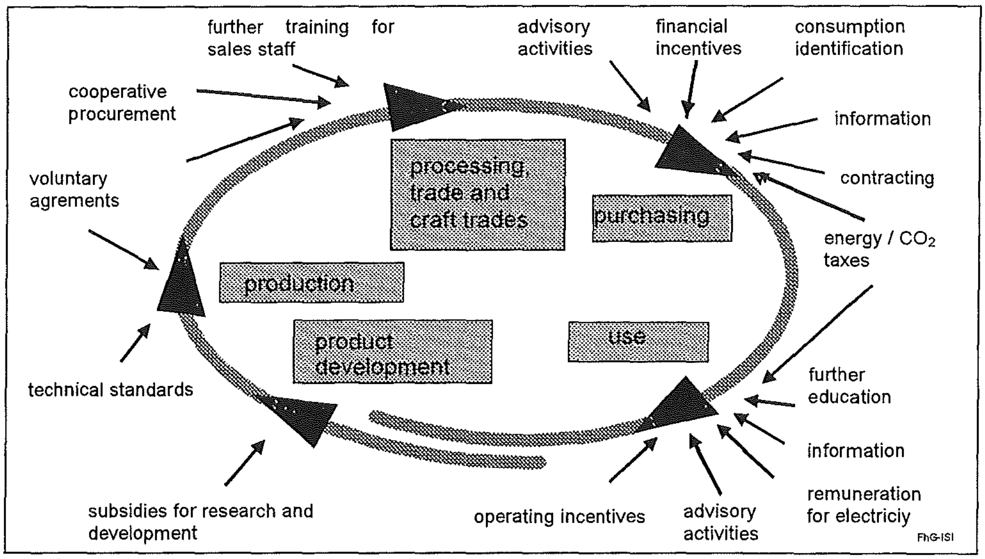
Climate policy measures aim in particular at exploiting additional possibilities of reducing energy consumption and substituting energy carriers. In comparison to a situation without such interventions (reference development), the objective is to exploit the economic potential more rapidly and - if necessary - also to mobilize mitigation options which are not (yet) economic.

- If this involves economic possibilities of emission mitigation (e.g. by improved energy efficiency, energy carrier replacement, recycling) in many cases sector-specific obstacles are encountered which are dependent on the phase in the product's life cycle and can be reduced, eliminated or avoided by appropriate measures (Figure 2-1).
- Projects which are not (yet) economic can be encouraged above all by specific financial incentives or by raising energy prices, however sometimes also by intensified development to reduce costs or measures for cooperative procurement.

A consideration of the product life cycle as well as the actions in a concrete project makes it immediately apparent that often not only is a single obstacle to be overcome but rather a whole package of obstacles. Correspondingly, rarely is just one measure taken to reach a goal but rather a whole package of measures (Figure 2-1). However, designing a suitable package of measures requires the most transparent information possible on the effects of the individual measures and the combined effect of the package.

Figure 2-1

Measures for Overcoming Obstacles to Innovation in the Product Life Cycle of CO_2-Mitigating Investments



In this chapter, the objectives and problems of impact analysis will be considered in more detail from the methodological perspective. Attention is focused on the question of what is meant by measures (2.1.2), their impacts (2.1.3) and methods of impact analysis (2.1.4). Important conceptual distinctions concern e.g.

- technical, sectoral and policy-instrumental categories of "measures",
- technology-related, sector-related and over-arching measures,
- individual measures and packages of measures,
- measures already in effect and others (approved, planned or proposed),
- present and future impacts of measures,
- short-term and long-term impacts,
- isolated and integrated analyses as well as
- strategy analyses and impact analyses.

2.1.2 Types of Measures

Policy versus Technical Measures

The emission mitigation achieved or aimed at can basically be differentiated according to various systematic classifications. Of principal significance here are technical, sectoral and policy-instrumental categories which are (only) in part related to each other:

- From the *technical* perspective, investments and organizational changes for energy savings or energy-carrier substitution are frequently called "measures", e.g. thermal insulation in older buildings, energy-saving driving techniques in passenger road traffic and the use of wind energy converters.
- In the *sectoral* respect, sectors such as households, small-scale consumers, industry, transport and energy supply can be differentiated and deeper disaggregations can be undertaken.
- On the level of *policy* instruments, in contrast, in addition to government activities directly affecting allocations (e.g. infrastructure measures, statutory requirements), economic incentives and sanctions are of particular significance influencing the behaviour of private individuals.

As a rule, policy does not consist of structural changes, e.g. in an "expansion of cogeneration", but rather in measures to promote such changes. However, the methodological demands made on impact analysis are much greater if they are to be based on policy-instrument categories instead of technical or sectoral categories.

In the terminology of General Economic Policy, the policy makers' opportunities for intervention are known as *instruments*. Instruments can be subdivided according to type (intervention fields, degree of precision, role of the state) and intensities (breadth of the intervention field, intensity of compulsion) A (policy) *measure* is taken to mean the application of an instrument with a certain dimensioning in a concrete situation. Policy *alternatives* generally refer to *combinations* of measures. In order to assess the alternatives, their *consequences* must be compared with respect to (policy) *packages of objectives*.

In economic systems based on decentralized decisions by economic subjects, (policy) measures usually only have an indirect effect. In order to analyse the impact of such measures, the reaction of those affected and the consequences emanating from them must be investigated.

In the discussion of energy policy, certain modifications to the energy demand or the structure of the energy system are frequently also termed measures (e.g. greater use of renewable energies, increased thermal insulation, expansion of cogeneration). As a rule these activities are implemented by private producers and consumers and must therefore not be equated with policy measures even if they are politically influenced. In order to make a differentiation they are termed *technical measures* or *changes in behaviour.* From the perspective of energy policy, these changes can generally be interpreted as consequences in the sense of intermediate goals.

Information, influencing opinion, negotiations, price alterations and direct standardization of behaviour are types of instruments with different levels of intervention intensity on the part of the state and correspondingly restricted scope for action on the part of private individuals. The lower the level of intervention intensity, the more difficult is it to estimate the impacts of measures.

Technology-related, sector-related and over-arching measures

Measures concerning energy and environmental policy can be subdivided into technology-related, sector-related and over-arching measures according to their target group. Technology-related measures improve or impair application conditions for individual technologies or technology sectors. Whereas their primary effect concerns individual technologies, as a rule the conditions for the application of other technologies are also altered (e.g. an increased application of cogeneration can reduce the potential for in-house heat recovery). This is correspondingly also true of sector-related measures. As in the case of general measures or those affecting several technologies or sectors, attention must be paid in impact analysis to interdependences in the overall energy system.

Individual measures and packages of measures

The impacts of individual measures are often more difficult to assess than packages of measures. In terms of practical policy, purely individual measures restricted solely to the application of one instrument are rare since as a rule several obstacles must be overcome simultaneously. Even within the framework of individual laws or directives, several instruments are more frequently applied at the same time and moreover several objectives pursued. For this reason, the conceptual differentiation between individual measures and packages of measures is fuzzy. There is a fluent transition ranging from single measures up to whole programmes.

2.1.3 Impacts of Measures

The impacts of measures generally consist in altering state variables which be causally attributed to the measures under consideration. The impacts of measures should therefore be measured in principle by a - in part hypothetical - comparison of a situation involving a measure (or measures) and a (reference) situation without this measure (or measures). In particular the (disaggregated according to sector) energy consumption and emission of greenhouse gases are regarded as state variables here. The relevant questions are therefore, e.g. ex post: "How would the emissions have developed (in comparison with the actual course) if certain measures had not been taken in the past?", or ex ante: "How would the emissions develop (in comparison to a reference case "without these measures") if certain measures were taken in the future?"

Interdependences

Due to interdependences, the impact of a package of measures can differ considerably from the sum of the impacts of single measures. Even if the concept of a single measure were restricted further in the sense of an independent political activity, its impacts cannot be considered in isolation from other strategic activities. The impact relationships of measures are in part complementary (e.g. improved information, financial support for facilities and removal of obstacles in licensing procedures), in part substitutive (e.g.

measures for improving heating plants and those for improving thermal insulation) and in part alternative (e.g. initial advice with a loan programme or contracting). In such cases, the potentials of different mitigation options are dependent on each other. This is also true of the impacts of measures by different actors on the levels of the Federal Government, the federal states and local authorities. Furthermore, other interdependences of the energy system require an integrated overall analysis.

Measure Status and Time Reference of the Impacts

The Federal Government's catalogue includes both measures already taken as well as those planned. This is also the case in many other National Reports. Moreover, additional measures must be considered for achieving the goals set. In addition to the status of the measure (planned, in preparation, approved, implemented), the duration of the programmes and the prospects of follow-on activities after they have been concluded may also be of significance. In the final analysis, the period during which the measures can take effect is decisive.

International commitments display a relatively short time reference. However, up to the years 2005 and 2010 changes in the energy system are only possible to a considerably more restricted extent than in the longer-term perspective. The necessity of quantifying in particular short-term goals should, however, not lead to the long-term effects receiving too little attention in strategic considerations.

Impact analyses must be differentiated according to whether they are to be implemented ex post or ex ante. Evaluations of programmes or projects already implemented may largely be restricted to ex post analyses with the aid of empirical methods. Issues for the future, however, result from the temporal influence of the measures. The major difficulty of empirical methods is isolating the impact of certain policy measures from the influence of other factors.[3]

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[3] For example, it is very difficult to isolate the impacts of special efforts within the framework of voluntary agreements by industry from the impacts of other measures such as loan programmes for medium-sized enterprises, further training, information and initial advisory activities by energy agencies .

It is primarily ex ante analyses that will be required to achieve future goals (such as in the National Reports in accordance with the FCCC). An ex post analysis of the previous effects of climate protection measures is of relevance here to the extent that existing overall evaluations and general principles for forecasts must in part be adapted to the current status. Furthermore, on the basis of past experience with evaluations of previous programme impacts, reference values for quantifying the specific impacts of present and future measures may possibly be obtained, with causal chains observed in the past being transferred to the future. In practice, more or less significant restrictions may arise if the empirical correlations are not significant or if the assumption of the (econometric) structural constancy[4] does not apply.[5]

2.1.4 Analytical Methods

Empirical methods are of little significance for prospective issues, particularly in cases where changes are to be studied of a type or extent not observed at all in the past. For this reason, empirical price elasticities, for example, can only play a limited part in the analysis of the impacts of drastic climate policy measures.

Furthermore, the information content of econometric methods for the impact analysis of overall strategies is also limited by the fact that numerous methods (information, advisory services, further education, regulatory measures) are of a qualitative nature and corresponding empirical analyses only lead to results of little reliability even with a high level of effort. For these reasons, economic approaches are more or less dependent on the postulation of plausible behavioural measures (of rational or to a certain degree rational behaviour). A frequent criticism is that insufficient attention is paid to technical possibilities in purely economic approaches, although in connection with energy and environmental issues they can be crucial.

[4] In econometrics, this is taken to mean the time invariance of the empirical behaviour equations and their parameters.

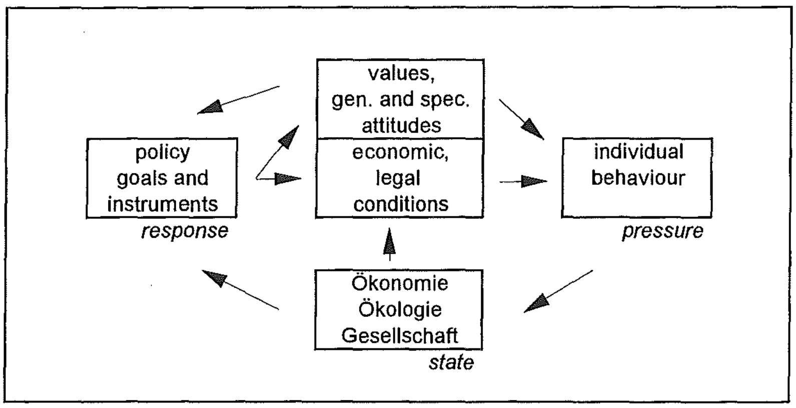
[5] Added to this, potential savings are in part limited (e.g. the possibilities of substituting natural gas for coal).

On the other hand, purely technically oriented analytical procedures cannot lead to satisfactory answers on their own since they do not explicitly model economic actors or institutions (in particular no behaviour-, knowledge- or legislation-related obstacles).

It thus becomes apparent that the impacts of policy measures within the framework of climate protection scenarios can ultimately only be analysed on an interdisciplinary basis by applying different methodological approaches from the individual disciplines and systems research.

Figure 2-2

Extended Model of Environmental Behaviour



In addition to technological aspects, the assessment of environmental policy measures must also consider political, ecological, economic, sociological and sociopsychological factors. This interrelationship is illustrated schematically in Figure 2-2 on the basis of the sociological behaviour model (Diekmann 1997).

Attention is focused on the determinants of individual environmental behaviour. These comprise, on the one hand, dimensions of environmental awareness such as values and attitudes and, on the other hand, economic and statutory restrictions. Individuals' behaviour alters the state of the environment, the economy as a whole and society both directly and indirectly. Policy has an indirect effect on behaviour, both by modifying economic and statutory conditions as well as by changing values and attitudes. The goals and instruments of policies are not influenced solely by the state of and modifications to ecological, economic and social "reality" but also by individual value judgements, as for example expressed in the acceptance of policy goals and measures.

Both direct environmental behaviour and the acceptance of governmental measures are influenced by environmental knowledge and (particularly special) attitudes towards environmental concerns.[6] In addition to material incentives and the elimination of institutional obstacles, environmental policy therefore also basically requires publicity and persuasion.

Isolated and integrated analytical approaches

In analysing the impacts of policy measures a differentiation must be made according to the degree of consistent and transparent assignment of impacts between purely qualitative data, isolated expert judgements and (partial or integrated) model analyses.

A restriction to qualitative assessments is inevitable in such cases where the measures themselves cannot be adequately represented in a quantitative form, where data on the impact path are missing or considerable interactions exist.

Quantitative expert judgements comprise the definition of the measure or package of measures, estimates of the primary impacts (impact on those directly affected), estimate of secondary impacts (repercussions, bandwagon effects etc.), estimate of the technical measures initiated (e.g. installation of facilities), calculation of impacts on the energy economy (e.g. substitution effects), and calculation of the impacts on emissions; added to this are (at least qualitative) assessments of the measures according to other environmental and overall economic criteria (cf. Section 3.4.1).

An isolated analysis of the impacts of individual measures may possibly lead to erroneous estimates due to effect relationships with other measures and the general inter-

[6] These interrelations are subject to considerable changes in the scale of social priorities over time (e.g. today: unemployment, crime, pensions, incomes, environment). Changes in the scale of priorities also involve changes in the energy consumers' perception and readiness to take decisions and thus the impact of climate policy measures.

dependences of the energy system. Overall integrated analyses of the energy sector therefore display basic methodological advantages over separate estimates on the basis of expert judgements. Furthermore, attention must be paid to links with other sectors of the national economy.

However, for their part, quantitative energy models also encounter two limitations:

- There is no model which could adequately simulate all the facets of the technical, economic and political opportunities for emission reduction.
- Even very simplifying models generally require considerable effort for the provision and processing of suitable data.

Moreover, models are formulated for certain issues. For these reasons, in practical applications expert judgements, which in addition to the impacts of isolated measures should also contain data on interdependences and various model-assisted analyses must complement each other.

Strategy and impact analyses

A quantitative assignment of goals can thus be made in a strategy analysis as well as within the framework of an impact analysis, where attention is focused on different issues. Whereas goal-oriented strategy analyses study which options are beneficial for achieving certain goals, in impact analyses the attempt is made to derive the impacts of predefined measures on certain targets. Goal-oriented emission scenarios are frequently derived by using the optimization methods of linear programming (LP), where the results are essentially determined by technical parameters and cost variables. With more or less fundamental reservations, such LP models can also make a contribution towards resolving issues in impact analysis (cf. Section 2.3.3). However, determining the impacts of energy and environmental measures ultimately requires a mental experiment in which the reactions and interactions are simulated - without being restricted to optimal development and including both institutional conditions and human behaviour (cf. Section 3.1).

2.2 *International Comparison: Methodological Approaches in the First National Reports by the States Party to the Framework Convention on Climate Change*

In order to obtain a first overview of the methods used for the impact assessment of measures for reducing energy-related CO_2 emissions, the National Reports from 25 states party to the Framework Convention on Climate Change available by March 1997 were analysed. Table 2-1 following gives a survey of the results. A more detailed description can be found in Kunz, Holtrup (1997).

It was discovered that the National Reports display considerable differences in the form of information provided, which - together with other factors such as different systems of data collection, different data quality, different study periods or initial data (e.g. climatically adjusted values) - restrict their comparability.

In four cases (Greece, Hungary, UK, USA), a complete catalogue of measures was quantified with respect to the impact of its individual measures. Quantification of the reduction potentials is very uneven in all other National Reports. For example, some countries made a separate representation of sectoral and overall reduction potentials, although individual measures in the respective sectors were not quantified. Other countries only presented the overall reduction potential without any breakdown according to sectors. Furthermore, in the representation of the sectoral reduction potentials it remained unclear whether the reduction potentials of individual measures had been added up or overlap effects considered.

In the representation of sectoral reductions it cannot be clearly seen whether only the pure mitigation effects of the reduction measures have been listed or whether - as in the case of Hungary - the general, economically related emission development has been included. It is therefore not possible to consider the impact of individual policy measures in isolation from general economic trends. A breakdown of the representation into, on the one hand, a scenario presenting the development of CO_2 emissions without any corrective measures and, on the other hand, a detailed representation of the effect of individual measures would be very desirable particularly with respect to the rapidly changing economic situation in the countries of Central and Eastern Europe, which is very difficult to calculate.

It was largely measures in the field of increasing technical efficiency and reducing emissions as well as energy-carrier substitution that were quantified. Impacts in the field of behavioural changes (e.g. advice, training) and market measures (e.g. CO_2 tax) were not calculated by the countries. Only in four cases were reduction effects due to behavioural modification (Hungary, UK) or by a CO_2 and energy tax (Netherlands, Sweden) identified. However, no information on the methodological procedure is available.

In spite of specific standards laid down by the Climate Secretariat - the methodology of the reporting displays great disparity. In the individual National Reports, the measures were incorporated in the impact analysis to varying extents. Classification into measures implemented and those planned was not handled in a uniform manner either. If specified at all, the reduction estimates are based on different types of assumption. For example, an internalization of the external costs is only considered in exceptional cases - e.g. Denmark. In the same way, the external CO_2 emissions of electricity imports are rarely included; once again the exception is Denmark. In some cases climate-adjusted values are used as the initial data, as in the case of Denmark, the Netherlands and Switzerland.

Not all the National Reports show how the individual measures have been quantified for an impact assessment, i.e. how the countries modelled the reduction measures, what potential savings were assumed and how the absolute reduction potential in million tCO_2 was deduced from the potential energy savings. Many National Reports listed data for isolated reduction measures, but only in the USA's Technical Report was very detailed information given on the quantification of the individual measures *and* on the respective methodological procedure.

The impact analysis of the catalogue of measures is frequently not processed by government agencies alone but also by nongovernmental and scientific institutions (e.g.: Austria, Switzerland). In order to obtain more detailed information on the models used and the methodological procedure, the corresponding publications by the institutions involved would have to be consulted.

Although many countries gave details of expected reduction potentials, no information was given on the calculation models used. Such countries include Austria, the Czech Republic, Denmark, Finland, France, Italy, Japan, Latvia, the Russian Federation, Spain and Switzerland.

The other countries applied a broad spectrum of models. Primarily macroeconomic models were applied as well as energy and emission models. Depending on the country, the different models were either used singly or in combination. Moreover, consideration was either given to the entire energy system or only sectoral segments. Once again, it must be borne in mind that the different methodological procedures and the various models with their individual parameters lead to results which are not comparable.

It must be emphasized here once again that the above statements refer to the *first* National Report by the states party to the FCCC. The second National Report is now due, and a first assessment on the basis of 15 reports by the "Annex I Countries" has been made available by the Subsidiary Body for Implementation of the FCCC (FCCC 1997). In comparison to the first National Report, the assessment acknowledges the superior quality of the new National Reports, in particular with respect to the transparency of basic assumptions for projections of energy-related CO_2 releases. Nevertheless, fault was still found with the great differences in handling policies and measures as well as different levels of information, an unsatisfactory treatment of safeguards measures, in some cases a lack of information on the models used, on costs and also the in part indeterminable number of measures. No significant progress was perceived in the assessment of uncertainties. On the whole, there still seems to be a considerable need for developing the methods and harmonizing them until the necessary requirements of comprehensibility, comparability and transparency of the National Reports have been achieved.

Table 2-1

Information on Impact Assessment of Measures for Mitigating Energy-Related CO_2 Emissions in the First National Reports

Country	Method	Model	Measures Considered
Australia	a. BAU scenario b. impact assessment measures c. mitigation scenario	a. energy, transport model b. studies, models c. from the difference between a. and b.	measures implemented
Austria	a. reference scenario b. reduction scenario (including impact assessment measures) c. stabilization scenario	n. d.	a. measures imple mented b. / c. measures implemented and planned
Canada	a. forecast of final energy demand b. impact assessment measures c. mitigation scenario	a. macroeconomic model IFSD b. sectoral models c. from the difference between a. and b.	measures by the federal government, the states and provinces implemented and under implementation
Czech Republic	a. BAU scenario b. impact assessment measures	n. d.	measures implemented
Denmark	BAU scenario (1993) and impact assessment measures (energy and transport sector separately, for 2000 and 2005)	n. d.	measures implemented from 1990 measures implemented and planned (from 1994)
Finland	a. BAU scenario b. impact assessment measures c. mitigation scenario	a. n .d. b. n. d. c. from the difference between a. and b.	b. / c. selected implemented measures
France	a. reference scenario A b. reference scenario B c. moderate / central scenario (incl. impact assessment measures)	n. d.	c. measures implemented and planned
Germany	a. BAU scenario b. mitigation scenarios c. impact assessment measures	n. d.	b. measures implemented (up to 1995)

Country	Method	Model	Measures Considered
Greece	a. BAU scenario b. reference scenario c. 3 $/barrel CO_2 tax scenario d. 10 $/barrel CO_2 tax scenario e. various technical sce narios b. - e. incl. impact assessment measures	n. d.	b. - e. measures implemented and planned
Hungary	a. BAU scenario a. energy saving scenario (incl. impact assessment measures)	a. / b. mass balance method	measures planned
Ireland	reference scenario	n. d.	measures implemented and planned
Italy	a. BAU scenario b. impact assessment measures c. mitigation scenario	n. d. c. from the difference between a. and b.	measures implemented
Japan	a. BAU scenario b. long-term energy forecast c. impact assessment measures	a. n. d. b. n. d. c. from the difference between a. and b.	measures implemented
Latvia	a. pessimistic scenario b. reference scenario (including impact assessment measures c. optimistic scenario	n. d.	b. measures implemented and planned
Netherlands	a. energy policy scenario b. impact assessment measures c. other scenarios for comparison	macroeconomic model CENEKA, various submodels LMS, FACTS, ATTACK, SELPE, RIMplus	a. measures implemented b. measures planned (from 1994)
New Zealand	a. BAU scenario b. impact assessment measures c. mitigation scenario	a. energy and emission models b. n. d. c. from the difference between a. and b.	b. measures implemented c. measures implemented d. and planned

Country	Method	Model	Measures Considered
Norway	a. emission forecast, medium-term (incl. Impact assessment measures) b. emission forecast, long-term	a. macroeconomic model MODAG, submodels b. equilibrium model MSG	b. /c. measures implemented (incl. CO_2 tax)
Poland	a. emission forecast, medium-term b. emission forecast, long-term	a. macroeconomic / energy models b. macroeconomic / energy models	a. / b. no measures considered
Portugal	emission forecast (including impact assessment measures)	n. d.	measures planned and realized
Russia	a. optimistic scenario b. realistic scenario (including impact assessment measures) c. pessimistic scenario	n. d.	b. measures planned
Spain	a. BAU scenario b. reference scenario (including impact assessment measures)	n. d.	measures implemented
Sweden	a. BAU scenario b. reference scenario c. impact assessment measures	a. /b. MARKAL optimization model MACRO macroeconomic model c. MARKAL optimization model	b. /c. measures implemented
Switzerland	energy scenario (including impact assessment measures)	n. d.	measures implemented
UK	a. reference scenario b. impact assessment measures	n. d.	measures implemented and planned
USA	a. BAU scenario b. impact assessment measures	a. IDEAS instruments (expanded FOSSIL 2) b. IDEAS instruments, submodels	a. measures imple mented b. measures planned

n. d.: no data;
BAU: business as usual
From: Kunz, Holtrup (1997)

2.3. *Possibilities and Limitations of Formal Models*

2.3.1 Problem Areas

In the present National Reports drawn up within the framework of the FCCC, the elements described in Section 2.1 are found in different combinations - to the extent that corresponding quantitative data are provided. Depending on the method and data situation, the quantifications are specified as a total relative to individual sectors, techniques, groups of measures, programmes or single measures. As a rule, previously initiated activities are given as well as additional activities, although the time reference of the impacts often reamins unclear.

In many countries, isolated estimates are apparently undertaken and integrated models used as well. In keeping with the differentiation between strategy and impact analyses discussed above, energy models are used by some countries for quantifying goal-oriented reduction scenarios and by other countries for simulating impacts on the energy and emission sides.

In interpreting the results of model-assisted scenario analyses, the differentiation of simulation and optimization models is of major significance. This does not solely involve methodological differences in model formulation but above all the issues for which the model has been developed. Furthermore, an adequate interpretation of model results presumes knowledge of the mechanisms mapped endogenously in the model and the variables exogenously predefined for the model. Against this background, two examples of simulation and optimization models will be considered in more detail in the following with respect to the combination of expert judgements and model applications.

The general validity of quantitative analyses depends decisively on the quality of the data on which they are based. Problems of uncertainty, which occur particularly with longer-term forecasts, are therefore treated separately in Section 2.3.4.

2.3.2 Application of a Simulation Model with the Example of DOE Methodology

A particularly in-depth discussion of the methodological procedure is given in the USA's National Report (Department of Energy 1994). Starting from a list with 247 options, 146 measures are first described in detail and then condensed into 50 actions, of which 31 actions concern the reduction of energy-related greenhouse gases. The actions are essentially defined as the deviations of a policy scenario (combined policy case) from a reference development (administration baseline) derived from a modification of an existing forecast (EIA Annual Energy Outlook 1993). As a first step, isolated estimates were performed by experts for the impact analysis ("stand-alone analysis"). The technical and structural estimates on which the assessments are based are given for each measure. Public expenditure and private investments are indicated for each measure and energy cost savings as well as greenhouse gas reductions for (sub)groups of measures.[7] An integrated overall analysis of the energy-related measures was performed by the IDEAS (Integrated Dynamic Energy Analysis Simulation) model, which represents a further development of the Fossil2 model.

Of interest in this connection is the extent to which, with the aid of the simulation model, the integrated analysis leads to different results from simply adding up the harmonized expert judgements. Whereas in the expert judgements overlaps of potential and synergy effects have already been taken into consideration, the interdependences of measures on the demand side were only investigated by the model in a few cases. Since the data from the expert judgements had been considered in the model there were hardly any discrepancies with respect to demand-side actions between the sum of the estimates and the model results. The same is also true of the supply-side measures.

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[7] The measures are assigned to the following groups:

- Commercial Energy Efficiency Actions: Partnership Programmes; Development, Commercialization, and Training
- Residential Energy Efficiency Actions: Appliance Improvements; Home Improvements
- Industrial Energy Efficiency Actions: Accelerated Efficiency; Pollution Prevention
- Transportation Energy Efficiency Actions
- Energy Supply Actions: Enhanced Natural Gas Utilization; Enhanced Renewable Commercialization; Improved Performance of Existing Zero Emissions Technology (Hydro); Improved Energy Efficiency
- Methane Reduction and Recovery Actions
- HFC, PFC, and Nitrous Oxide Reduction Actions
- Forestry Actions

Considered as a whole, the results of the case study by the American Government are thus essentially based on independent assessments by experts whereas the integrated overall analysis with the aid of the simulation model primarily served to check general consistency.

2.3.3 Opportunities for Applying Optimization Models with the Example of the IKARUS Model

Optimization models oriented to energy technology can be used for the following problems in the context of assessing climate protection policy:

a) Derivation of technical target scenarios for identifying desirable structural changes to the energy system in comparison to a reference development (cost minimization with predefined maximum emissions as a decision estimate for the economy as a whole).
b) Derivation of restricted projections on the future structure of energy systems on the basis of exogenous forecasts of the factors determining energy consumption (cost minimization as an explanatory model for decentralized decisions).
c) Approximative estimate of the impact especially of measures directly influencing technical parameters or the costs of energy technologies or energy carriers such as energy taxes, subsidies etc. (cost minimization as an explanatory model for decentralized decisions).[8]

d) Analysis of the consequences for the energy economy of incentives estimated exogenously to the model (cost minimization as a restricted explanatory model for decentralized decisions). This taken to mean, for example, estimating the impacts of a single technology on the overall system, where the level of the input (e.g. production) is exogenously predefined for the model in the form of a restriction.

[8] Whether the impacts of an energy tax or subsidies can be estimated by an optimization model still remains a matter of controversy. Critics point to a violation of the assumed model philosophy according to which taxes do not represent monetary expenditure. Furthermore, taxes, whose true characteristic is a steering effect, do not have any influence on the demand for energy services in the model - in contrast to reality.

Although applications (a)and (b) do not refer to impact analysis, nevertheless they may be of interest in this context. The derivation of technical target scenarios (a) shows that the policy goals can be achieved at least in terms of technology and indications can be obtained of the technology lines which should be used more intensively taking economic and ecological aspects into consideration. The major application of such optimization calculations is cost minimization for predefined maximum emissions as a decision estimate for the whole economy. Optimization models such as the IKARUS-LP model, MARKAL and EFOM discussed in Section 3.3 were developed for such purposes.

In addition, by deriving reference scenarios, the quasi-prognostic application (b) permits a comparison with status quo forecasts obtained on the basis of other methodological approaches - taking imperfect markets into consideration.

In contrast to case (a), the cost minimization in case (b), as in cases (c) and (d), is to be regarded as an approximative approach towards explaining decentralized decisions.

Applications (c) and (d) are directly aimed at aspects of impact analysis. However, the difference between (c) and (d) is to be found in the fact that in (c) the attempt is made to explain the reaction to certain policy measures by analogy, whereas in (d) only the consequences regarding the energy system are investigated with the linear energy model, where the behaviour reactions have to be exogenously predefined.

In case (c), suitable interfaces with the model must be identified to analyse the reactions: import prices for taxes, investment costs for investment subsidies, variable costs for operating and maintenance costs, minimum use for government demonstration problems, relaxed maximum use for removing restrictions on use and demands for reducing the required energy services.

With respect to the model application (c) - i.e. direct impact analysis on the basis of linear optimization - reservations primarily arise from the following points:

- Significant obstacles for investors and energy consumers are not explicitly mapped in the model.
- Institutional and statutory conditions cannot be considered.

- The behavioural assumption of cost minimization is at best approximative; other motives, limited information and rationality cannot be covered.
- Imperfect markets do not lead to the optimum coordination of plans applying to individual economic units implicit in the model.
- Different parameter constellations are valid for some decision-making situations applying to individual economic units (especially with respect to funding, taxes, depreciations, solvency).

As a consequence of discrepancies between a consideration of individual economic units and the economy as a whole, not only do discrepancies arise in the monetary evaluation approaches but also in quantifying and interpreting the fundamental bounds.

Impact analyses in the sense of (c) are therefore possible for some of the political measures using the LP model; however, due to the restrictive conditions they must be complemented by different analytical approaches even for those quantified measures which can be taken into consideration.

With a few exceptions concerning individual technologies (such as nuclear energy), hardly any experience has been gathered in analysing policy scenarios for the application of LP models according to approach (d) so that the benefits of such a path cannot yet be assessed. The disadvantage (or advantage?) of this approach is that the primary and secondary effects of policy measures (may) have to be determined outside the model. The major task of the model application is thus to ensure internal consistency in analysing the consequences for the energy economy, in which connection the relevant emissions could also be determined at the same time. Assuming reliable data, the analysis could also easily be extended to other greenhouse gases and climate-forcing emissions.

As part of this approach, economic incentives for applying a technology could be indirectly modelled as an increase of its minimum application. If competitiveness has already been established, the reduction of statutory restrictions could be considered as raising - previously suitably reduced - upper bounds. This therefore restricts or expands the solution space, thus retaining the optimization function of the model - even if in a modified sense. The fraction of favoured technologies would thus be increased more or less exogneously. Although the optimization would lose general validity with respect to cost-minimum strategies nevertheless the adavantage would be a consistent determination (of the differences) of system costs and of overall emissions paying attention to interdependences within the energy system.

The IKARUS model and its applications within the framework of the "Policy Scenarios for Climate Protection" research project are discussed in Section 3.3.

2.3.4 Significance of Uncertainties and Long-Term Aspects

In comparison to non-formal calculations on the basis of expert judgements, formal models for simulating or optimizing the energy supply can make a particular contribution towards increasing the degree of consistency and transparency of assumptions and results. However, the models themselves cannot solve the information problem, which is primarily due to the fact that particularly for forecasts many model inputs involve great uncertainties.

A differentiation must be made here between general uncertainties and those specific to the model type. Whereas for simulation models the specifications and parameters of reaction functions and adaptation mechanisms are decisive, the results of techno-economic optimization models mainly depend on assumptions concerning technical parameters, restrictions and costs.[9] Largely independent of the model type, there is the basic difficulty that the future development of the general data of the analysis is uncertain. This is equally true of non-formalized scenario calculations.

The boundary conditions of forecasts for the energy economy primarily concern the development of the leading variables of energy demand as well as the general economic development, changes in the sectoral economic structure, demographic developments and social change. Added to this are uncertainties about central parameters such as the future development of energy prices dependent on the world market.

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[9] For very long-term time horizons (more than 20 years) the analysts run out of ideas on concrete technology and cost developments in most final energy sectors, particularly in industry.

Future analyses cannot be based on unambiguous prophecies about future developments but on *qualified* forecasts of exogenous analytical variables and in part simply on "plausible" assumptions (stakes). Although there are a number of different methodological approaches for including the associated uncertainties in model analyses, nevertheless these approaches are mainly based on considerations of probability theory which model the influence of risks but cannot reduce the basic uncertainty. In practice, attempts are made above all with the aid of sensitivity calculations and scenario variants to take the phenomenon of uncertainty into consideration. This can contribute towards not overinterpreting individual quantitative analytical results.[10]

The time dimension is of particular significance in this connection since in general the degree of uncertainty concerning future developments increases with the distance of the time horizon. As a rule it is therefore much easier to estimate the impacts of climate protection measures e.g. in 2005,[11] than to derive corresponding statements for the year 2020 or indeed 2050.

Not only does the uncertainty concerning central general data increase with an increasing analysis period, but also with respect to impact analyses the impact mechanisms of policy measures are to be weighted differently in a long-term consideration than within the framework of a short-term analysis (cf. Section 2.1). It must be particularly remembered here that in the course of time the direct impacts of policy measures subside whereas indirect effects, whose quantification naturally involves greater uncertainties, may tend to increase.

Another long-term aspect generally concerns the leeway which, for different technical, socio-economic and political reasons, increases with the horizon. In the longer term, greater changes in the energy system are therefore possible than with a short-term con-

[10] On the other hand, the increasing range of results may reduce the general applicability of the analyses with respect to conclusions for policy. The way in which the results are presented is therefore also important.

[11] The analysis presented in Vol. 1 and Vol. 2 was restricted to this time horizon.

sideration. Options may in part be exploited in the long run which do not even occur with a short-term analysis.[12]

The reasons for this are to be found in the time required for

- research and development, e.g. in the field of solar technology,
- market development and decreasing costs, e.g. wind energy,
- changes to long-lived structures, e.g. in the building stock or power generating untis,
- planning and construction of large-scale projects, e.g. large nuclear power plants or solar imports,
- implementation of policy changes, e.g. international harmonization,
- changes in human behaviour and life style.

The remark that in general "more is possible in the long term" should not be misinterpreted as an invitation to shelve adaptation measures. On the contrary, due to the considerable period of time required for realizing some strategies intiatives must be taken in good time. Furthermore, a wait-and-see approach may under certain circumstances even lead to potentials not being sustainably used, e.g. if opportunities are lost of implementing structural changes cost-efficiently in the reinvestment cycle.

[12] This is particularly true of indivisible projects, for which yes-no decisions apply in the individual case.

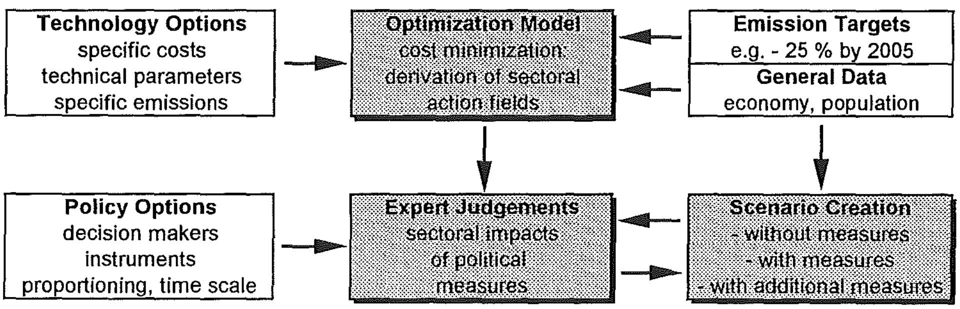
3 Combined Approach for Deriving Policy Scenarios

3.1 Overview

In this chapter it will be shown how a technology-oriented optimization model and policy-related expert judgements can be combined to derive policy scenarios for climate protection (Figure 3-1).

Figure 3-1

Combined Approach for Deriving Policy Scenarios



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Within this framework, the optimization model makes a special contribution towards identifying sectoral action fields in the sense of cost-efficient technology options. Of decisive significance here are the predefined national emission targets which must not be exceeded. Other important influential factors are general economic and demographic data and the technology options available in the period under consideration characterized by specific costs, technical parameters and specific emissions.

Paying attention to these technology-oriented action fields, expert judgements have the aim of quantifying the impacts of appropriate policy measures on sectoral energy consumption and emissions. An essential prerequisite is the most accurate possible description of the policy options to be analysed.

In a further step the sectoral assessments, initially performed in isolation, are linked together and consolidated to form scenarios for the energy economy as a whole. Particular attention must be paid to impacts in the conversion sector and in interdependences of the impacts of measures between sectors which could make feedback to the expert judgements necessary. A comparison of the results of the "with additional measures" scenario with those of the "with measures" scenario is particularly important for policy conclusions.

The scenario concepts of relevance here (without measures, with measures, and with additional measures) will be discussed in detail in Section 3.2 following. The application of linear optimization models and, in this context especially the IKARUS model, is discussed in Section 3.3. Against this background, Sections 3.4 and 3.5 will show in more detail, with examples for Germany, how expert judgements are undertaken in the individual sectors and how the sectoral results are combined and consolidated to form policy scenarios.

3.2. Scenario Concepts and Energy Statistics Data Basis

3.2.1 Scenario Concepts

The central goal of the study consists in describing scenarios for the development of the energy economy on the basis of impact assessments of individual measures for emission reduction, from which as a result the overall development of emissions within a region can be read off. This presupposes the clearest possible definition of the scenarios to be considered, an unambiguous assignment of the measures to the respective scenarios, as well as the avoidance of double counts in the impacts of measures.

With close reference to the corresponding international agreements in connection with the FCCC, three scenarios must be differentiated:

- In a *"without measures scenario"* it is assumed that target-oriented measures for climate protection policy have not been taken in the past nor are they expected in future.[13] This scenario is to be regarded as a theoretical construct to identify different policy intensities between the Annex I states.

- In contrast, a *"with measures scenario"* describes a development which considers all climate protection measures actually implemented so far. Corresponding to the characterization according to the FCCC Guidelines (FCCC 1996) measures merely planned or announced are not taken into consideration. This concerns, for example, the intention of introducing a Europe-wide CO_2/energy tax, the realization of which from a current perspective remains completely open, although supported by the Federal Government.
- A *"with additional measures scenario"* includes - in addition to those already taken - additional measures whose implementation could in principle be appropriate for realizing a defined reduction goal.

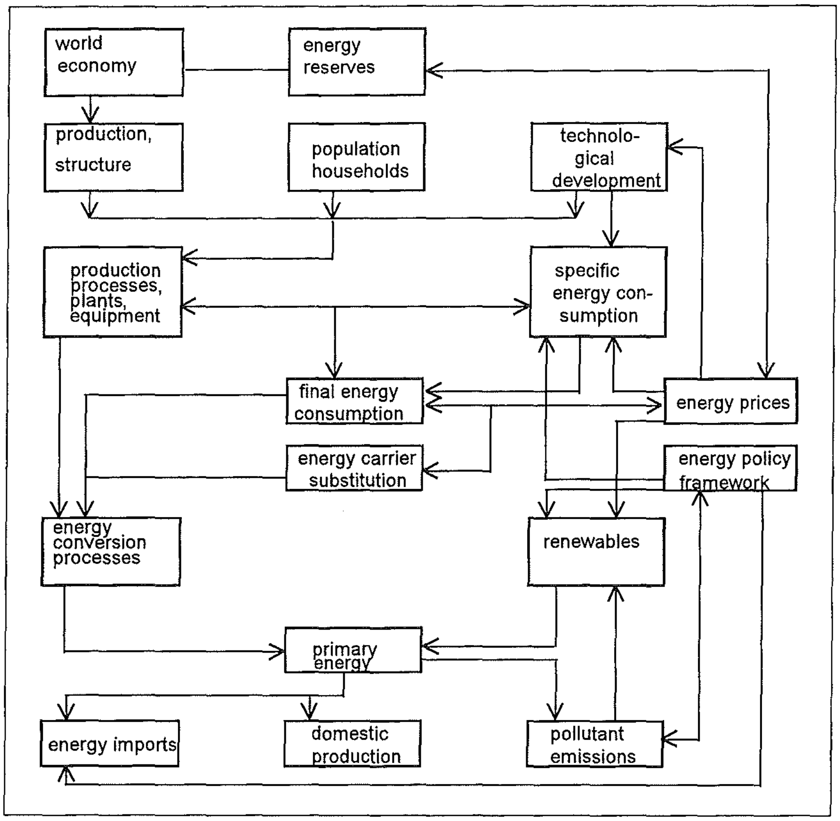
In compiling the scenarios, it has proved very beneficial to make use of a comparatively up-to-date *forecast* of the energy economy as one of the bases. This involves the forecast presented in 1995 by Prognos AG, Basel, on behalf of the German Federal Ministry of Economics (Prognos 1995). The projectins were based on assumptions concerning the most important general data on the economy as a whole and demographic developments, energy prices, technological changes, behaviour of energy consumers and suppliers as well as activities by political decision makers.

A further benefit for the scenario work that this forecast was structured in an extremely differentiated way according to sectors, energy use and energy carriers. This particularly enabled the quantitative effects of the measures included in the scenarios to be consistently simulated and compared in a very specific manner. Figure 3-2 gives a survey of the basic structure of the forecasting system used (Prognos 1995).

[13] A *"without measures scenario"* is to be interpreted as a "frozen policy" scenario. It can thus be essentially differentiated from a so-called "frozen efficiency" scenario in which unchanged sector-specific energy consumption values are hypothetically assumed.

Figure 3-2

Basic Structure of the Prognos AG Forecasting System



This projection, which may essentially be characterized as a status-quo forecast, is intended to represent *one* probable development of the energy supply and demand as well as CO_2 emissions. It takes into consideration all climate protection measures taken or planned up to early 1995. To this extent, it closely resembles the concept of a *"with measures scenario"*.

In order to create the transparency required by the FCCC Guidelines, it was necessary to also assess the impacts of the measures already considered in the forecast, especially since only in this way was it possible to describe a development of CO_2 emissions which would ensue without the corresponding climate protection measures. This *"without measures scenario"* was calculated by correcting the CO_2 emissions estimated by Prognos AG by the emission-mitigating effects of the measures (in concrete terms: increased).

In a next step, the climate protection measures implemented by the Federal Government up to mid-1996 were identified. The results of the "without measures scenario" were corrected by the effects of the above-mentioned measures so that the respective emission impacts were reduced by these values. The result was the *"with measures scenario"* quoted in the Second National Report by the Federal Government (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) 1997; Ziesing et al. 1997).

With a view to the year 2005, the Federal Government has set itself extremely ambitious reduction goals which would not be achievable with the measures taken so far shown in the "with measures scenario". The discrepancy between the goals and the level of achievement expected in this scenario makes it necessary to discuss additional measures which appear suitable to fill this gap. The paths towards achieving this are indicated in a *"with additional measures scenario"*.

Figure 3-3

Schematic Representation of the Relation between the Scenarios

CO_2 Emissions According to the Forecast by Prognos AG (Basic Forecast)

\+ CO_2 mitigation effects of climate protection measures considered by Prognos

= **Without Measures Scenario**

\- CO_2 mitigation effects of the climate protection measures taken up to mid-1996

= **With Measures Scenario**

\- CO_2 mitigation effects of climate protection measures additionally considered for reaching the goal

= **With Additional Measures Scenario**

The relation between the basic forecast by Prognos AG and the three scenarios under consideration here is shown schematically in Figure 3-3. In Table 3-1, the way in which individual measures are assigned to the respective scenarios is shown in more concrete terms, as well as the transition between the scenarios with the example of climate protection measures in the industrial sector. It is particularly important to consider possible overlaps in the individual impacts of measures to exclude double counts from the very beginning; this is expressed in the differences between the row values "weighted total of individual measures".

3.2.2 Energy Statistics Data Basis

In interpreting scenarios it must generally be remembered that their information content decisively depends on the quality of the basic data. In forecasts of the energy economy, technical parameters, cost variables and the general data relevant for the energy demand of the overall economic and demographic development always involve uncertainties which increase with the breadth of the analysis horizon. Furthermore, in the course of time the direct impacts of policy measures subside whereas indirect effects, which can, however, only be estimated with even greater uncertainties, tend to increase. This is particularly true of the longer-term impacts on technical progress, market development and life style.

However, an adequately supported and differentiated database for the energy economy, as available for Germany with the energy balances presented here, is also of considerable significance. These energy balances present a detailed overview of interdependences in the energy economy in the form of a matrix. They do not only permit statements to be made about the consumption of energy carriers in the individual sectors, but also provide information on their flow from production up to application in the various generation, conversion and consumption sectors.

Table 3-1

Derivation of Scenarios on the Development of CO_2 Emissions in German Industry[1] (data in million t CO_2)

Without Measures Scenario	**122.5**
Measures Taken	
ERP energy savings programme	0.6
Tax concessions for combined heat and power	0.0
Thermal Insulation Ordinance	0.4
Ordinance on Heating Facilities	0.6
Investment programme for the mitigation of environmental pollution	0.6
EU eco audit	0.0
Amendment to the Ordinance on the Execution of the Federal Immissions Control Act (Ordinance on Small Firing Installations)	0.1
Energy, technology and building research	0.5
Voluntary agreements by industrial associations/VKU	10.5
Voluntary agreements by VKU, BGW, MWV, VDEW, VIK	0.3
Activities by federal states and local authorities	2.5
Unweighted sum of individual measures	*16.1*
Sum of individual measures adjusted by overlappings	*15.4*
With Measures Scenario	**107.1**
Additional Measures	
Ordinance on Heat Use	6.5
Amendment to the Thermal Insulation Ordinance	1.0
Ordinance on the Use of Electricity	[2]
Ordinance on the Letting of Buildings	0.1
Ordinance on Property Tax	0.0
Supply of "green electricity" by public utilities	[2]
New BDI/VDEW/VIK/VEA association agreement	2.1
Improvement of the ERP, DtA, KfW loan programmes	1.5
Specific further training programme	1.3
Initial advisory services and information on energy agencies	0.3
Support for the secondary capital market	0.4
Contracting promotion	0.4
Improved targets for voluntary agreements	3.0
Increased research and development	1.3
Deliberate procurement programmes by large enterprises	0.7
Copying Brundtland towns; programmes by federal states/local authorities	1.1
Unweighted sum of individual measures	*19.7*
Sum of individual measures adjusted by overlappings	*7.9*
With Additional Measures Scenario	**99.3**

[1] Only fuel-related emission mitigation; emissions related to electric power are considered by means of changed power consumption quantities in the power plant sector.

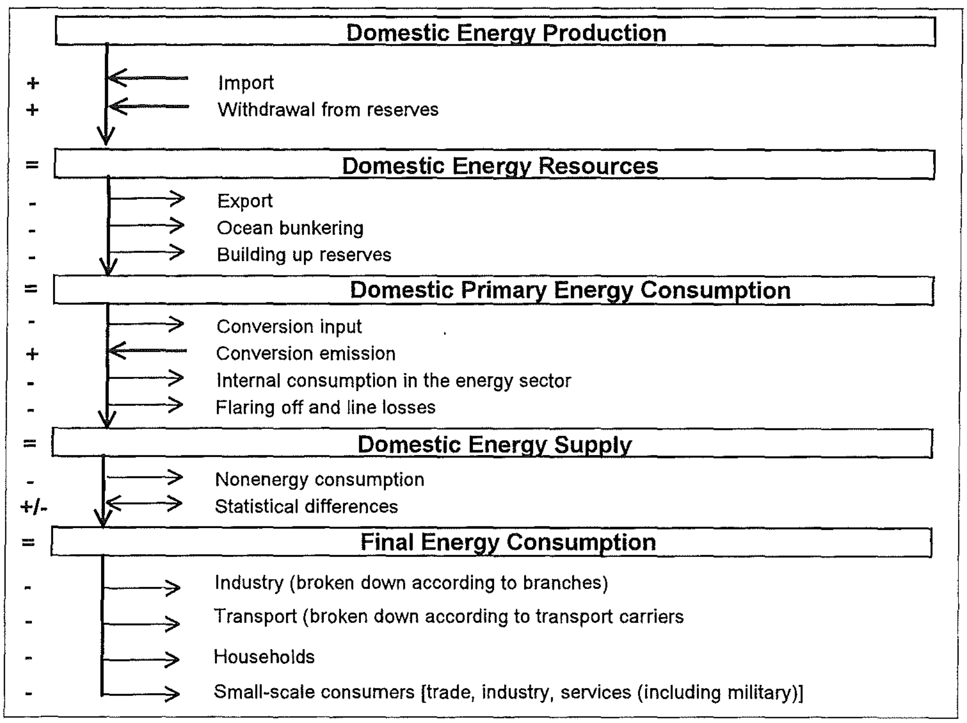
[2] Only power-related mitigation taken into consideration by modified electricity consumption quantities in the power plant sector.

According to their structure and validity, energy balances occupy a central position in the energy data system. They are also the basis for determining CO_2 emissions and thus an essential element for the national reporting obligations ("inventories") undertaken in connection with the FCCC.

The horizontal layout (columns) of the energy balance matrix shows the energy carriers with their energetic and also nonenergetic uses. The energy resources, energy conversion and final energy consumption are shown in the vertical layout (rows). Each column therefore identifies the resources, conversion and utilization of the respective energy carrier according to the schematic summarized in Figure 3-4.

Figure 3-4

Schematic of the German Energy Balance



The scenarios and measure-oriented impact analyses largely follow the sectoral breakdown of the energy balances on the basis of which the corresponding CO_2 emissions are also determined. It must be noted that within the final energy sectors of industry, transport, households and small-scale consumers, initially only the *direct* CO_2 emissions and their changes are taken into consideration by the respective climate protection measures assumed for the scenarios. The *indirect* CO_2 emissions resulting from the use of secondary energy carriers by final energy consumers are analysed in the conversion sectors, particularly the sectors of electricity and district heat generation. Emission-mitigation effects due to energy saving measures by final-energy consumers, which frequently also reduce the consumption of electric energy, are therefore first reflected in the conversion sector.

The sectoral breakdown of the German energy balance is not directly comparable with the structure agreed according to the IPCC/FCCC Guidelines. Adaptations are therefore necessary to ensure international comparability. The emissions associated with ocean bunkering are therefore not directly assigned to the individual nations nor those associated with international air traffic. Whereas ocean bunkering can be directly read off from the energy balances, this is not the case for international air traffic. Special definitions are necessary here; on the basis of empirical indicators it is assumed that about 80 % of the aviation fuel used to fuel civil aviation in Germany can be assigned to international air traffic. The emissions thus arising and those associated with ocean bunkering are therefore not a constituent of the national emission balance.

A few assignments are also necessary to harmonize the German energy balance/emission data with the internationally agreed sector structure. However, this exclusively concerns the final energy sectors, whereas no differences are apparent with respect to differentiation in the conversion sectors. In contrast to the energy balances, as mentioned above, emissions due to international air traffic are not assigned to the transport sector. The sector comprising households, small-scale consumers and trade according to the IPCC breakdown does not include emissions from mobile sources in agriculture, forestry and fisheries; the emissions arising here are specified together with the other final-energy sectors in the "others (including military)" group.

Although, all in all, the energy balances provide a satisfactory energy statistics database, there are some weak points and deficiencies with respect to the completeness and degree of differentiation of the existing energy-relevant information on individual energy consumption sectors and energy carriers (Messer, Ziesing 1992). This particularly concerns the lack of differentiation within the small-scale consumer sector, the limited coverage of renewables and the incomplete inclusion of reserve changes (which in the case of households and small-scale consumers leads to sales figures but not consumption figures for storable fuels being specified in the energy balances).

The majority of such deficiencies could be eliminated or at least reduced by implementing energy statistics legislation and by regular special surveys and studies ("detail definition studies").

3.3 Application of a Linear Optimization Model

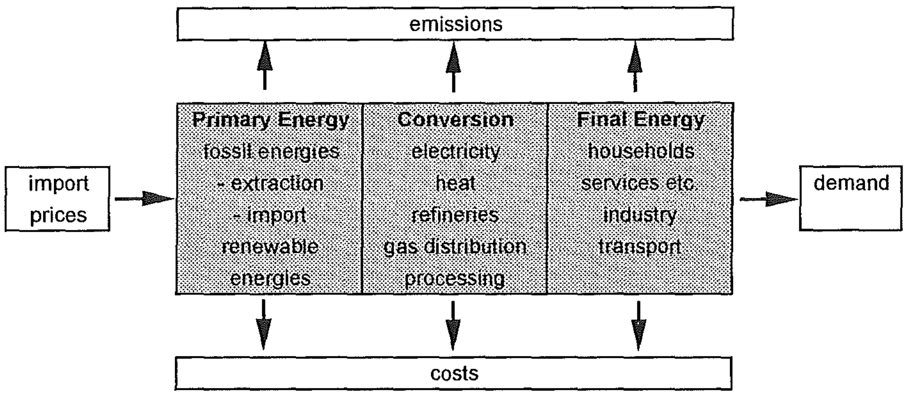
3.3.1 Advantages and Limitations of Optimization Models

With the aid of linear equations and inequalities, the IKARUS optimization model reproduces the processes of the energy economy in a simplified form (Hake et al. 1994). Such processes are the extraction or importation of primary energy, conversion into secondary energy and its distribution, as well as ultimately use by the final consumer. This means that the entire energy conversion chain is included. The system is interlinked in a complex manner since different primary energy carriers are used, various types of conversion stages passed through and eventually a wide spectrum of final energy forms supplied. A large number of conversion, transport and utilization technologies are applied for this purpose. In addition to technical and economic relations, the system is characterized by various energy boundary conditions.

The model reproduces the energy fluxes, emissions and costs of the entire energy system and optimizes the activities according to the linear programming method (Figure 3-5). An important optimization criterion is minimization of the overall system costs, where a maximum emission level can be preset as a boundary condition. Before discussing the application of the optimization model to analyse policy scenarios, the advantages and limitations of using an optimization model will be briefly touched on.

Figure 3-5

Basic Structure of the IKARUS Optimization Model



Goal: Minimization of overall costs with given emissions

Advantages of model analyses

- Computer-assisted models have a very high information processing capacity, i.e. large data volumes and *complex interlinkages* can be easily processed.

- By simultaneously processing the interlinked processes of the energy economy, the impacts of certain individual technological and policy measures on the overall energy system can be covered. For example, if within the framework of reduction strategies certain CO_2 savings measures are applied in the transport sector then their influence on other sectors can be directly indicated by the criterion of cost minimization. The advantage over an isolated analysis exogenous to the model is that *consistency* is ensured by taking the preset boundary conditions into consideration. Double counts can be ruled out and secondary effects of the energy economy included.

- The results are easily *reproducible* and verifiable. The databases can be continuously *updated* to include new developments.

- Various *scenarios* and *sensitivity analyses* on a certain issue can easily be compiled by systematically altering the input parameters so that certain hypotheses or energy policy objectives can be tested in the model, e.g. with respect to expected costs or emissions arising. The energy system's reaction to altered input parameters is analysed with the aid of the scenario technique. Sensitivity analyses comprise the systematic change of parameters or variables. Even minimal cost differences between competing technologies may lead to completely different solutions. Such effects are identified by sensitivity analyses in order to verify the robustness of a solution. Furthermore, sensitivity analyses can provide information on uncertainties (e.g. demand range, data uncertainties) and their impact on the entire energy system.

- Amongst competing technology options, the optimizing model selects those options which are most cost-effective for achieving the goal. By simultaneously including the supply side (conversion sector) and the final consumption sector in the optimization, it is possible to balance competing supply- and demand-side CO_2 reduction measures in order to minimize overall costs. The IKARUS model approach thus includes an essential aspect of the concepts of *least-cost planning*.

- The modelling of energy-economy issues and the model-assisted analysis improve the *appreciation of quantitative interrelations* in the energy sector, create a uniform terminological basis and thus make an essential contribution towards more closely defining arguments in energy policy.

Disadvantages, problems and restrictions in model application

- The models are large and complex leading to very high *manpower requirements* for developing and in particular for compiling the database. In the same way, the considerable *time required* for performing scenario and sensitivity analyses must not be underestimated, especially since knowledge of the model and data structure is indispensable for interpreting the results.

- Models are always a *simplified image* of a much more complex reality. The system boundaries (separating a partial reality) are defined on the basis of an issue. The technical system model, the mathematical system model and also the data model are formulated accordingly. The "art" of modelling essentially consists in identifying the most important interrelations against the background of the issue and converting them in the three models discussed above. Only thos relations can be included which - according to the state of the art - can be described mathematically. Certain political, social and psychological factors with a decisive influence on the behaviour of energy-producing and energy-consuming economic actors cannot currently be modelled in such models or only to a very limited extent. Such inadequacies must then be overcome in practical modelling by abstract assumptions and restrictions. The model results must therefore be regarded as "if/then statements" of a hypothetical nature and must not be overinterpreted.

- Optimization models provide numerical frameworks for decision-making processes in energy policy, however their results are *not forecasts*. If, for example, an optimum strategy is calculated by the model then this does not mean that this will, as it were, automatically gain acceptance in the future energy economy. Taking exogenous requirements into consideration, a solution generated by an optimization model designs the most favourable structure of the energy system according to the target criterion. Such an optimum solution can be interpreted in the sense of a design target as the best solution pathway. However, since in reality actors in individual economic units act according to individual criteria, the actual development of the energy economy diverges from the optimum solution outlined by the optimization model. The reason for this may be imperfect markets, other motivations, fiscal decision-making parameters deviating from the model or obstacles such as the investor-tenant dilemma in the building sector. A minimal-cost system thus only approximates to reality. In any case, political measures (such as directives, initial and in-service training or incentives) not simulated in the model must be taken in order to realize an optimum development.

- The model can configure an energy system in a cost-optimal manner but it does not develop *its own creativity*. The selectable technologies or savings opportunities must be specified in advance by the model user. They are then input into the data set and thus made available to the model as an alternative.

- The *modelling of actors' behavioural patterns* represents a basic difficulty in all energy-economy models. In models oriented to economics, the attempt is made, for example, to model behaviour as a reaction to changes of prices and income in the form of elasticities. Such coefficients of elasticity are derived from past data and used for a future projection. In the technology-oriented IKARUS optimization model, elasticities of this type are not modelled. The actors' behaviour is predefined in the form of upper and lower bounds. In the IKARUS optimization model the exogenous demand for energy services is not coupled to a change in energy prices or costs. A consideration of this nature must be performed outside the model.

3.3.2 Application of the IKARUS Optimization Model for Policy Scenarios

In the analysis of policy scenarios a differentiation is made between a "without measures scenario", a "with measures scenario" and a "with additional measures scenario" (cf. Section 3.2). The "with measures scenario" includes reduction measures already taken. In order to identify action fields for additional measures necessary to achieve the national reduction goal, the IKARUS optimization model is applied as follows:

1) A reference scenario is formulated for the target year 2005, which is to be interpreted in the sense of a scenario without any emission reduction targets. According to the model calculations, this means that the desired reduction target of 25 % in comparison to 1990 will not be achieved.

2) In the reduction scenario for 2005, the model has a predefined mitigation of CO_2 emissions in comparison to 1990 of 25 % under otherwise identical assumptions. The model determines the technology mix with which this target can be achieved at minimum cost.

3) The possible action fields can be identified by comparing the reduction scenario with the reference development. CO_2 mitigation contributions from the individual sectors can be specified as well as combinations of technologies within the sectors and the corresponding additional expense.

4) The results and the findings from previous steps must be intensively analysed. Realization issues must also be discussed against the background of the time remaining up to 2005. The plausibility of the results can also be verified by a comparison with historical developments.

5) The action fields and technology combinations identified form the background to the impact analysis of policy measures with the aid of expert judgements (Section 3.4).

3.3.3 Cost Calculation in the IKARUS Optimization Approach

In comparison to conventional economic studies the cost-minimizing IKARUS approach displays some special methodological features. Thus, for example, the IKARUS model does not perform any economic investment calculations in which expected income is usually compared with expected expenditure by investment mathematics. Income is not required since the economic efficiency of individual projects is not monitored. The IKARUS cost minimization aims at comparing the costs of alternative solutions for the same energy service. The decisive aspect is that the overall costs are minimized across all system elements, i.e. energy carriers and energy technologies. In the model, technologies on the energy supply side (e.g. extension of power plants) compete with final-consumer technologies (e.g. electricity-saving technologies). This corresponds to the procedure in least-cost planning, i.e. an integrated planning of energy supply and energy use. In the model this is applied simultaneously to all energy carriers and technologies in all generating and consuming sectors of the energy economy so that all the options compete with each other. It is therefore not so much the absolute value of the individual costs which are of relevance for decision-making but rather their relations or differences.

In order to perform an optimization the costs of the individual system elements must be made comparable. A simplified method is used for this purpose, whose most important characteristics are:

- The regular annual payments are calculated for all technologies by a uniform long-term discount rate and related to the useful lifetime of the respective technology.

- Costs which cannot be causally assigned to the processes of energy provision or production and operation of technologies are not included. This involves preferential rates, subsidies, grants and also taxes such as the mineral oil tax. It should be noted that taxes which cause the same relative load on all system elements are not relevant for optimization since they do not alter the cost relations.

The system of inequalities in the IKARUS energy model is mathematically underdeterminate and has infinitely many solutions. The solution leading to the lowest total costs is selected from this solution space with the aid of the so-called objective function. These total costs are composed of the sum of the direct costs of all the system elements. The direct-cost components are:

primary energy costs:	import prices, extraction costs and
technology costs:	production costs, fixed and variable operating costs.

Fixed operating costs are capacity-dependent and always arise irrespective of whether the facility is in operation or not. In contrast, variable costs are activity-dependent, i.e. they change depending on the quantity of energy converted by a technology. The variable costs do not include any fuel costs because energy costs are input into the system in the form of primary energy costs and, as it were, are passed on internally from technology to technology. In order to determine the cost of capital, the investments (production costs) including the interest for the construction period are converted into regular annual payments. On this basis, the system costs are calculated by the model in the form of annual costs. In interpreting these overall annual costs, it must be remembered that they consist of a mixture of cost fractions from various technologies with different lifetimes: e.g. in the transport sector 12 years for passenger cars and in the building sector 40 years for thermal insulation. The average reduction costs per CO_2 unit derived from the system costs represent the ratio of additional expense for a reduction scenario in comparison to a reference scenario for the CO_2 savings achieved.

Among competing technical options, the optimizing model selects those most favourable for achieving the target. The most cost-effective options are first exhausted and then successively the next most expensive until the CO_2 reduction target has been reached. The costs occurring in the reduction of the final CO_2 unit are known as marginal costs or shadow prices. These shadow prices are included in the model due to the special mathematical properties of linear programming. However, in the analysis it must be noted that in the individual case bounds may considerably alter the shadow prices. The marginal costs indicate how expensive a further CO_2 reduction is and they therefore represent a useful variable for the analysis.

3.4 Expert Judgements of Sectoral Measure Impacts

3.4.1 General Procedure

The methodological procedure in expert judgements of the impacts of individual measures is discussed in this section. On the basis of sector-specific conditions and action mechanisms as well as an uneven availability of data, a sectoral consideration is chosen here, starting from the general approach of the study. The methodological information concentrates on describing how the impacts were assessed in the "Policy Scenarios for Climate Protection" project (Ziesing et al. 1997) and how the analysis of individual measures and packages of measures could be refined in future. Section 3.5 shows how the partially derived results of sectoral analyses are transformed into strategic policy scenarios.

Taking into consideration the general goals and problems of estimating the impacts of climate protection measures described in Section 2.1, the impact analyses initially performed on the expert level can be shown to be roughly based on the following *steps*:

1. definition, classification and the most precise description possible of the measure or package of measures,
2. estimate of primary impacts (impacts on those directly affected by the measure, e.g. investors and energy consumers),
3. estimate of secondary impacts (repercussions, bandwagon effects etc.),
4. estimate of the technical measures initiated (e.g. construction of plants or organizational changes),
5. calculation of impacts on the energy economy (e.g. energy efficiency and substitution effects),

6. calculation of impacts on emissions and
7. as far as possible other (qualitative) assessments of the measure according to environmental, economic and social criteria.

Although not the subject of the actual estimates of impacts, a *classification and precise description* of the measure under consideration is of basic significance for the validity of impact analyses.[14] The following should be given as specifically as possible,

- who the initiator and sponsor of the measure is,
- which objectives are being pursued,
- which political instruments are applied,
- how the measures are proportioned,
- which target groups, sectors or technologies are directly affected (adversely or favourably),
- which reference the measure has in time and space, and
- which status has been achieved by the measure (implementation status).

Relations to additional measures are of interest, such as restrictions on the cumulation of preferential treatment or the necessity of focusing measures for overcoming several simultaneous obstacles.

The above-mentioned definition elements at the same time form important criteria for a classification of the measures, which should be applied uniformly to achieve comparability of the estimated results. The following *categories of measures* have been included in the study (with decreasing intensity of government intervention):

- regulatory measures (prohibitions and requirements),
- price-policy measures (prices, charges, taxes),
- subsidies (tax relief, funding aid, grants),

[14] The FCCC Guidelines: Policies and measures, Geneva 17 July, 1996 require a description of the measures (according to sectors) on the basis of the following criteria: objective, type of instrument, interaction, status of implementation, functioning, monitoring, impact, cost (to the extent possible); the following features are prescribed there for a tabular evaluation: name (* = not in baseline), type of instrument, objective, method, sector, status of implementation, impact (2000, 05, 10, 20), monitoring.

- infrastructural measures (especially investment by central, regional and local authorities),
- research promotion (especially financial project support),
- information measures (advisory services, public information, further professional training),
- voluntary agreements (on the basis of negotiations with other actors) and
- other measures (e.g. cooperative procurement, energy services).

In addition to this breakdown according to types of measures and further classifications according to policy level, departments, objectives, sectors, time reference, status etc., the quantifiability of the measure also represents an essential criterion. This is also related to the issue of direct and indirect impact mechanisms and the applicability of different qualitative and quantitative methods of impact analysis. As far as limiting time and effort for the respective analyses is concerned, a rough a priori assessment of the level of the target contribution of the measure may be meaningful.

Whereas the definition and classification of measures already implemented is relatively simple on the basis of literature searches, adequate concretization of planned or merely considered measures meets with considerable difficulties, particularly if the basic features of the measure are still controversial or undefined; a documentation of the basic assumptions is particularly necessary in such cases so that the analyses remain transparent.

In a second step, the actual impact analysis begins with an estimate of *primary impacts* focusing on impacts on the target groups or technologies directly affected. Reference values are, for example in the case of subsidy programmes for certain investment projects, the predefined level of support and the grant rates as well as predefined quotas, for instance with respect to technologies to be supported.[15] The preferential investments determined on this basis (or rather their contributions to emission reduction) should, however, not be confused with the (net) impacts assignable to the measure as a whole.

[15] The primary impact is difficult or impossible to assess in a number of categories because its direct impacts cannot be identified in the investments but rather only indirectly (e.g. research and development, information, further training and infrastructural measures).

In a third step, the attempt should be made to quantify the order of *secondary impacts* in the sense of repercussions and bandwagon effects. Repercussions are taken here to mean impacts caused indirectly by third parties. An example of this is emission reduction activities by copycats. Furthermore, the particular goal of many support programmes is to initiate a market development for new technologies which will later be self-sustaining. If this were to succeed emission savings mobilized in the longer term could be far higher than the direct contribution provided by the projects actually supported. However, in principle negative repercussions of climate protection measures are also possible, e.g. if by stepping up support for some technologies other emission-saving technologies are supplanted. Bandwagon effects, which can never be quite ruled out particularly in the case of support programmes, may lead to a restricted impact of measures. In this connection, the bandwagon effect is taken to mean claiming a benefit even in cases where an emission-reducing activity would have been implemented in any case, i.e. even without preferential treatment.

In the fourth step, the *technical or organizational measures* initiated as a whole are to be specified to such an extent that - making use of expert knowledge - their contribution to energy savings can be quantified.

Moreover, in a fifth step on the level of expert judgements, *impacts on the energy economy* are to be considered, where the major questions are which energy carriers and energy systems can be replaced by the conservation measures.

On this basis, an (initial) assessment of *impacts on emissions* can then be undertaken in a sixth step. However, these calculations can only be regarded as provisional since the interdependences of the energy economy cannot be considered or only in part.

Over and above quantification of energy and emission effects, within the framework of expert assessments a further, at least qualitative *assessment of measures* should be performed if possible according to ecological, economic and social criteria.

The specific procedure for the impact analysis of climate protection measures naturally depends greatly on the respective type and form of the measure under consideration.

Attention is therefore focused on aspects which differ from measure to measure due to the specific starting points and modes of action (Table 3-2).

The procedure outlined here serves as a general guiding principle for the analyses to be performed sectorally. The assessment procedure appropriate in the individual sectors must be specified in each case and due to special sectoral features may also differ from the process described here. Of decisive significance here are not only the impact mechanisms which differ from sector to sector but also issues of data availability.

Within the framework of a sectorally oriented analysis, special attention must be paid to consistent treatment of intersectoral measures, examples of which are certain measures in the sectors of advisory services, information, education and further training as well as research and development. In contrast, greater difficulties are encountered in the qualitative analysis of the impacts of general energy or emission taxes. The Federal Government has made the introduction of an EU-wide revenue-neutral CO_2/energy tax which does not affect competition dependent on a corresponding resolution on the EU level and has thus ruled out national go-it-alone strategies. The impacts of *general* energy taxes have not been analysed in detail in this project.[16]

For the quantitative analyses, a reference development for the energy economy has been formulated in this project based on Prognos (1995). The estimates of sectoral measure impacts are oriented towards the three scenarios discussed in Section 3.2: In addition to a hypothetical "without measures scenario" and a "with measures scenario", corresponding to the reference development, particular attention is paid to a "with additional measures scenario" which could enable the Federal Government to reach its climate protection goal by the year 2005.

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[16] For an impact analysis of energy taxes affecting the economy as a whole cf. the DIW studies Bach et al. (1995) and Bach et al. (1997).

Table 3-2

Measure-Specific Aspects of Impact Analyses

Type of Measure	Specific Aspects of Impact Analysis
Regulatory measures	Scope of application, exemptions, provisions to safeguard existing standards (e.g. buildings, vehicles), volume of construction output, safe-guards, contingency plans, competing options, obstacles, sanctions
Price-policy measures	Tax features, exceptional situations, possibilities of compensation, price elasticities of energy consumption, substitution elasticities, effects of resource allocation, profitability of efficiency and substitution investments
Subsidies	Grant rates, volume, continuity, application procedure, profitability of investments, bandwagon effects and repercussions, institutional obstacles, funding conditions, substitution effects
Infrastructure measures	Intensity of use, target groups, model function, substitution effects, competing investment projects
Research and development promotion	Stage of technological development, proximity to the market, time to maturity, dissemination potential, quality and cost effects, competing systems, acceptance restrictions
Information, advisory services and further education	Relevance of existing information deficiencies, target groups, multipliers, opinion formation, acceptance, motivation, dismantling obstacles
Voluntary agreements	Identification of special efforts (in comparison to business as usual development), competition with other measures (particularly regulatory and price-policy measures), possibilities for compensation
Other measures such as cooperative procurement, energy services	Potential for decreasing costs, learning curves, economies of scale, participation, acceptance, effects of professionalization and specialization

3.4.2 Conversion Sector and Renewables

3.4.2.1 Preliminary remarks

In many countries, the energy and conversion sectors are those with the highest CO_2 emissions. In Germany, these sectors account for 40 % of all CO_2 emissions, dominated by electricity and district heat. The other conversion sectors (e.g. refineries, coking plants, petrochemical plants) are not treated separately in this study since they are only responsible for a small share of the emissions.

In general, it must be remembered that emissions from the energy and conversion sectors essentially depend on energy consumption. As part of a sectoral impact analysis, the interdependences between the energy supply sector and the final consumer sector must be taken into consideration by an iterative method.

Renewables are in part utilized in the energy sector, especially in the electricity industry, but also in a decentralized manner in other sectors. Since renewables represent an independent field of action within the framework of energy and environmental policy, they should be treated together in the impact analysis (Section 3.4.2.3).

3.4.2.2 Electricity and district heat

Due to the high fraction of emissions, the electricity and district heat industry takes on particular significance. However, in the Federal Government's catalogue of measures aimed directly at the power station sector (apart from measures promoting renewables), only such research promotion is to be found which focuses on increasing efficiencies. Mention should also be made of the VDEW's voluntary agreement declaration. The CO_2-mitigating effect of this voluntary agreement (which involves, however, a number of conditions) results from increasing the efficiency of conventional power plants and improving the performance of nuclear power stations, in addition to increased utilization of renewables. Furthermore, the stage has been set in the EU for a liberalization of the electricity market. The Federal Government is striving to make the electricity sector more competition-oriented. With respect to climate protection, this will probably primarily lead to an increasing trend in favour of the generation of electricity from natural gas. Added to this are changes in electricity demand due to policy measures in the final consumption sectors.

As a whole, the emissions in the power plant sector would be about 25 million t or almost 8 % lower in 2005 in the "with measures scenario" than in the "without measures scenario". Compared with 1995, the emissions in this latter scenario remain practically unchanged. In the "with additional measures scenario" savings of 28 million t CO_2 could be achieved by an additional reduction of electricity consumption. Furthermore, a mitigation effect of more than 17 million t could be achieved if the fuel structure in electricity generation were modified. Such a structural change could be envisaged in an improved voluntary agreement. Taking into consideration overlapping in the impacts of measures, CO_2 emissions in the electricity industry could be about 44 million t or almost 14 % lower in the "with additional measures scenario" in 2005 than in the "with measures scenario".

In relation to emissions in Germany, the district heat industry is of relatively little significance. The importance of the district heat industry for climate policy arises in particular from the exploitation of the combined generation of heat and power. The mitigation effects in this sector largely involve the consequences of induced changes in the final consumption sectors.

3.4.2.3 Renewables

Relevance in the energy economy

With just 2 % renewables have only made a very modest contribution to the energy supply in Germany to date. They mainly involve hydropower, wood and refuse. According to Prognos 1995, although renewables will become more important in Germany in future, under status quo conditions only a minor exploitation of their potential is expected up to the year 2005 since many applications - without further support - are not profitable in individual economic units. In view of a "moderate" development of energy prices, this picture will change little for a number of technologies even up to the year 2020. The forecast basically starts from the current boundary conditions for energy policy. This includes measures already implemented by the Federal Government for promoting renewables such as the Act on the Sale of Electricity to the Public Grid. Consideration is also given to incentives initiated by demonstration programmes. Over and above this, as a rule consideration is only given to recognizable initiatives at a regional and local level. Without additional measures only a modest increase in renewables would be expected by the year 2005.

Measures for promoting renewables

In the past two decades, the Federal Government has applied a number of measures directly or indirectly promoting the use of renewables both at home and abroad. At the same time, the European Union, federal states and local authorities as well as individual companies have made in part great efforts in this sector. Added to this are various private, largely ecologically motivated initiatives. The importance attached to renewables in various departments at the level of federal policy also becomes apparent by the fact that more than one third of the measures specified in the First National Report by the Federal Government benefit renewables.

The wide range of these political instruments comprises cross-technology and technology-specific measures with various degrees of intervention by the government. This mainly involves price-policy measures, subsidies for demonstration, testing and application, research funding and various measures for information and for removing obstacles. The measures are directed towards different actors and target groups such as households, industrial companies, utilities, local government, certain plant operators, public institutions and science. Special support is given to the utilization of wind power, photovoltaic power, hydropower, solar collectors, heat pumps, geothermal energy and solid, liquid and gaseous biomass.

The contribution by renewables to the energy supply in Germany can in future only be significantly increased if it is supported by sufficient policy measures. As in the past, hopes cannot be pinned to one support instrument alone. The use of renewables encounters various obstacles which are in part technology-specific and in part concern different options simultaneously. It is therefore necessary to consider various combinations of policy measures. The assessment of packages of measures to promote the use of renewables must be embedded in strategic considerations with respect to the energy economy and policy sectors related to it as a whole. The suitable combination and intensity of sector-related measures may depend in particular on the form of a general energy or emission tax.

Special measures for promoting renewables have been debated in the past few years, for example in Discussion Group 6 at the Federal Ministry of Economics (BMWi 1994). The following can be mentioned as future fields of action for "broad-based" efforts:[17]

- measures for improving the competitiveness of renewables at home and abroad
- improving legal and administrative boundary conditions for the application of renewables as well as initial and further training and education
- market-oriented research, development and demonstration of facilities and materials for utilizing renewables.

Impact analysis with the example of remuneration for the sale of electricity to the public grid

The Act on the Sale of Electricity to the Public Grid has a special significance amongst the measures taken so far for introducing renewables into the market. However, the impact of this law, in force since 1991, on previous and future renewable electricity generation and the emission reduction thus brought about is not easy to calculate. The direct effect consists in improving the development of proceeds during the facilities' lifetime. Operators of existing facilities profit from this as well as investors who would have

[17] The demands include in particular a concept for financial support consisting of increased minimum renumeration for the sale of electricity to the public grid and in addition investment subsidies for a limited time for electricity generating plants whose profitability cannot be achieved by minimum renumeration for the sale of electricity alone, or corresponding operating cost subsidies, state subsidies for heat generation plants, the partial assumption of costs for connection to the grid by the utilities, export support for application systems or individual components, the introduction of a CO_2/energy tax, exemption from mineral oil tax for the biofuel fractions in mixtures, the abolition of investment oversight and licensing requirements for plants using renewables, the admissability of supplying neighbours, an improvement in cooperation with utilities in the energy-producing industry, privileges under building law, obligations to use solar installations, consideration of environmental benefits in legislation on nature conservation and water, and a relinquishment of compensatory and substitutive measures, elimination of obstacles in budgetary law, tenancy law and trade codes, measures for improved information, advisory services, training and further education and last but not least measures for promoting application-oriented research, development and demonstration.

erected the plants in any case thus leading to bandwagon effects in both cases. In contrast, the desired effect is to mobilize additional investments. Such incentives are effective above all for those projects which are on the threshold of profitability. Whereas on the one hand much more promising projects would also be realized without any increased remuneration, the economic assessment of very expensive projects is little changed by this measure alone. However, it must be remembered that the level of remuneration combined with other support measures may be of decisive significance even with great differences between prices and costs. Irrespective of the level of remuneration, the Act on the Sale of Electricity to the Public Grid plays a major role simply because the utilities are obliged to accept electric energy.

The previous effect is illustrated particularly clearly by the expansion of wind power in the past few years, encouraged both by the BMBF's 250 MW programme and additional programmes by the federal states. With the currently valid minimum remuneration, numerous projects are now economic even without state subsidies. Other projects have also been realized by the combination of several measures. The realization of these projects as a result of such measures also has positive repercussions on the further development of renewables. Future operators profit both from the demonstration of operation as well as from the improved supply conditions with respect to technical reliability, performance and cost.

The direct impact of the Act on the Sale of Electricity to the Public Grid on developments up to the year 2005 must be assessed differently from technology to technology. It should be particularly noted that electricity from utilities is not covered by the measure. The impact on other operators' readiness to invest requires other measures or at least a backup. For wind energy and hydropower these measures primarily consist in removing obstacles which have recently become more and more apparent. The isolated mobilization effect of increased remuneration will remain slight since in the period under study cost reductions are not expected in an order that would enable grid-connected facilities to reach the profitability threshold.[18] Bandwagon effects primarily occur with electricity from existing hydroelectric plants.

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[18] In this connection, it must also be remembered that in many local authorities a "cost-covering remuneration" is paid which is several times the minimum remuneration.

Overall impacts

Quantitative estimates of the impacts of previous and additional measures for promoting renewables on the level of carbon dioxide emissions for electricity-generating systems are essentially based on estimates of the supported rated power. By multiplying the latter by the related annual utilization time, the estimated annual electricity generation is obtained. With a view to emission mitigation, a substitution of electricity from medium-load power stations must be assumed for the technologies considered here. For heat-generating systems, attention must be paid to the energy carriers replaced.

According to the status quo forecast, in 2005 the expected use of renewables in Germany will bring about total savings of 36 million t CO_2. About a third of this amount would be achieved even without measures concerning energy and environmental policy. However, this figure should only be regarded as a guideline. Due to some double counting, the direct impacts of the measures considered will probably be smaller on the whole; on the other hand, there will also be indirect effects from combinations of measures. Renewables' contribution to the reduction figure in 2005 could be increased considerably in comparison to the status quo forecast by other measures (particularly in accordance with the above-mentioned proposals in BMWi 1994). The additional impact is estimated at almost 10 million t CO_2.

Due to the as yet relatively high cost of systems for utilizing renewables, monetary incentives such as funding aid and remuneration regulations are frequently crucial. Whereas qualitative measures such as information and the removal of institutional obstacles are effective in the sense of backup measures.

In the period up the year 2005 - and even until 2020 - it will only be possible to exploit a minor fraction of the long-term potential available from the technical, economic and ecological aspect. Assessments of policy measures for promoting renewables should therefore not merely be directed towards the amounts achieved until then but should rather also consider longer-term perspectives. This is particularly true of technology policy.

3.4.3 Industry and Small-Scale Consumers

3.4.3.1 Preliminary remarks

The sectors of industry and small-scale consumers are very heterogeneous, both from the technological and also the operational and business aspects: sectors with large companies or medium-sized enterprises, subsectors in the administration of large and small central, regional and local authorities, large branch operations and private service companies with very few employees give some idea of the range of different decision-making processes and insights into conditions concerning the energy supply (Gruber, Brand 1991, Weber 1997).

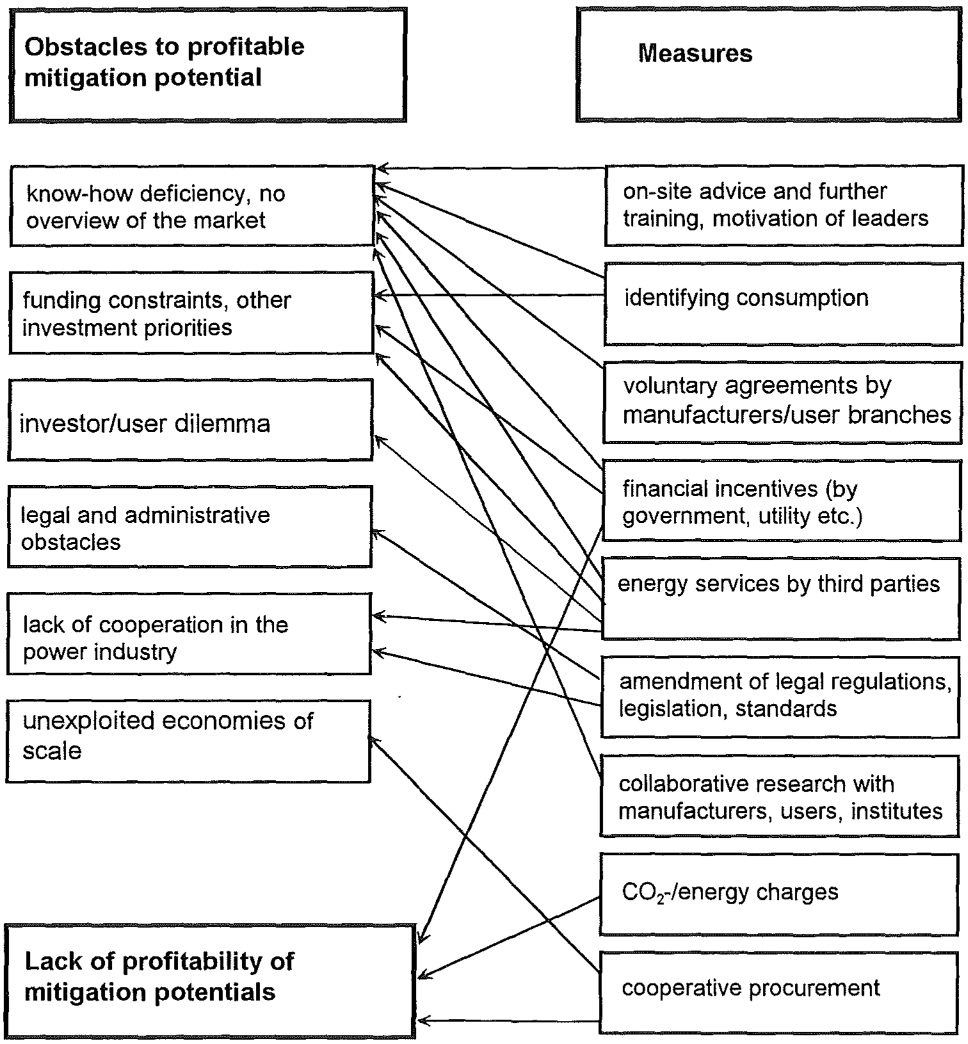
Due to the heterogeneity of the energy-consuming sectors of industry and small-scale consumers, there are a wide range of obstacles to efficient energy use and profitable energy substitution opportunities for the mitigation of greenhouse gases (cf. Figure 3-6). However, this diversity also leads to a broad spectrum of measures and packages of measures, which in part have to be conceived on a branch-specific basis due to the branch-specific process technologies, and in part tailored to the size of the company or to cross-sectoral technologies (e.g. with respect to combined heat and power generation, refrigeration or compressed air production) (ISI, Ifo, GEU 1993).

The wide range of obstacles leads, on the one hand, to the question of their position in the product life cycle (from the stage of research and development through production, further processing, trade, planning, investment up to and including use) in order to simultaneously apply appropriate measures to combat significant obstacles to innovation at the respective actors (cf. Figure 1-2 in Section 2.1.1). On the other hand, it is not unusual to find alternative measures or additive measures with a complementary effect - also frequently from third parties, e.g. by the federal states, local authorities, municipal utilities or new service companies - raising questions of synergy or overlapping effects in the impact analyses.

The relatively large number of measures or packages of measures necessary or possible in industry and small-scale consumers also leads to data from empirical impact analyses frequently not adequately describing the existing boundary conditions or the partial impacts of single measures (and frequently not being able to describe them for statistical reasons). In the sectors of industry and small-scale consumers reliance must therefore frequently be placed on expert judgements, which although they integrate empirical knowledge and technical information must nevertheless be adapted to the respective context by estimates.

Figure 3-6

Obstacles to Mitigation Potential and Possible Measures for Overcoming Them



A *typical approach* with these experts judgements in the industry and small-scale consumer sector is as follows:

- determination of the profitable energy efficiency and substitution potential identified either according to individual technology and then by extrapolations or by means of LP models (cf. Section 2.3.3),
- identification of major obstacles in the respective subsectors with the question of why the profitable emission mitigation potential has not been realized to the extent possible; identification grids are available for this purpose (cf. Figure 3-6 and the first pertinent literature (e.g. IEA 1987 or the MURE database described in ISIS et al. (1997)),
- assessment of the obstacle impact, i.e. the maximum theoretical mitigation potential which could be mobilized by the identified measures (e.g. refurbishment of all industrial and administrative buildings from the energy technology aspect in the maintenance cycle),
- assessment of the obstacle-eliminating impact of a measure or package of measures, which may make it necessary to precisely describe the measure (intensity, duration and degree of regional coverage).

As far as impact assessment is concerned it must be emphasized that *bandwagon effects* must not only be considered for financial incentives but also for other types of measures such as information and further training ("It's always the same people who turn up") or technical standards for new boiler plants with annual utilization rates perceptibly above the requirements of the Clean Air Regulation or the Ordinance on Small Combustion Plants, which would have been selected by some of the investors anyway on their own initiative. Empirical studies for branches, industry and small-scale consumers concerning these effects, which may differ greatly depending on the target group, are still few and far between (cf. also Bruce et al. 1996).

In adding up the impacts of several measures to form packages of measures, an explicit consideration of *synergistic effects* is often omitted because, according to experience, analysts tend to regard individual impacts as too great, i.e. they underestimate the strength of the obstacles. On the other hand, *overlapping effects* must then be explicitly considered if alternative measures by several actors simultaneously are assumed (e.g.

by the Federal Government, federal states and utilities) aiming at the elimination of the same obstacle and its potential. This is frequently the case for industry and small-scale consumers.

3.4.3.2 Industry

For the industry sector, 39 measures were first analysed individually with respect to their impacts up to the year 2005 for the "with measures scenario" and the "with additional measures scenario", of which 27 measures were then compiled to form two catalogues of measures for the two scenarios (cf. example in Table 3-3).

In the impact analysis of these two scenarios, in particular the *overlapping of measures* had to be calculated out, e.g. the overlapping

- of a specific further training course and initial advisory services from energy agencies (i.e. some of the companies took advantage of further training and invested their own know-how, whereas others made use of advisory services with reduced-rate consultancy fees),
- of support from a second capital market (e.g. with reduced-rate loans) and contract support by selective application on the part of the public purse enabling the creation of competence by contracting companies,
- the upgraded targets of voluntary agreements by the user sectors, which have to have a high degree of overlap since they are specified as gross reduction targets in which all the measures of other actors are incorporated. (Furthermore, this frequently also includes the sector-internal structural change towards less energy-intensive products, cf. DIW, FhG-ISI 1998).

In the first two cases of overlapping mentioned above, the impact of the individual measures was reduced by 30 to 50 % and in other cases the overlap frequently amounted to 10 to 20 %. In the case of voluntary agreements, the autonomous emission-mitigating measures were first subtracted as well as the impacts of CO_2-mitigation measures resolved by third parties in order to arrive at a "net effect" of voluntary agreements due to "special measures" by companies (cf. also Hillebrand et al. 1996, p. 71, and Ziesing et al. 1997, pp. 157-164). The impacts of more stringent targets for voluntary agreements by BDI and associations of the energy industry in comparison to the targets of March 1996 were then directly estimated as a net effect according to the general procedure outlined in Section 3.4.3.1.

The overlapping effect of the package of measures, in comparison to the total of individual measures, is clearly expressed for industry when the grand total of individual measures from both scenarios of 35.8 million t CO_2 is reduced on average by about 35 % so that the overall impact of the package of measures is only to be rated as just over 23 million t of CO_2 mitigation. In comparing the two scenarios "with measures" (a moderate climate policy) and "with additional measures", it is moreover striking that the overlapping effect in the first, moderate scenario is merely 5 % of the total emission mitigation and is considerably increased in the second scenario (cf. Table 3-3). This is quite understandable since with more extensive measures the number of energy-relevant decisions brought about by several instruments increases in the companies and businesses.

The uncertainty of estimates concerning the impacts of individual measures increases considerably due to a lack of knowledge and empirical data concerning factors such as bandwagon effects. The sum of the upper and lower estimates of the individual measures leads to an uncertainty range of about ± 20 %, which is not reduced overall for the package of measures, but rather - on the contrary - is probably even enlarged due to the uncertainties of the overlapping impacts (Table 3-3). This uncertainty range of at least ± 20 % of the total reduction brought about by a package of measures also reveals once again that the respective differences between individual impacts are rather to be interpreted as qualitative indications of important measures; otherwise there is a danger of regarding quantitative data as prognostic values.

Table 3-3

Package of Measures for Reducing CO_2 Emissions in the Industry and Small-Scale Consumer Sector in Germany in the "With Additional Measures Scenario"

Measures	CO_2 Reduction Contribution in 2005[1)] in million t CO_2
amendment to the Thermal Insulation Ordinance	6.0
Ordinance on the Use of Electricity	2.0
Ordinance on the Letting of Buildings	0.6
Ordinance on Property Tax	0.5
supply of green electricity	1.0 to 1.5
new association agreement BDI/VDEW/VIK/VEA	2.4 to 3.2
improved loan programmes ERP, DtA, KfW	2 to 4
specific further training programme	2 to 4
initial advice and information via energy agencies	2 to 4
support from the second capital market	1
contracting promotion	1
improved targets for voluntary agreements	5 to 10
increased research and development	2.5 to 4
specific procurement programmes by large enterprises	4 to 5
additional programmes by the federal states and local authorities	5 to 7
Total taking into consideration alternatives, technical restrictions and overlapping	23 to 32.5
[1)] incl. CO_2 mitigation by electricity savings	

From: Ziesing et al. (1997).

3.4.3.3 Small-scale consumers

In the small-scale consumer sector, a considerable number of measures for both scenarios were first analysed individually in accordance with the requirements of national reporting and their impact as an overall package of measures was then estimated by subtracting the overlapping effects. For some measures no estimate was performed due to a lack of knowledge of the impact (e.g. cooperative procurement) or only considered in the electricity sector (e.g. the impact of the Ordinance on the Use of Electricity and the "green rate").

In this sector the overlap between the individual impacts of measures in the moderate "with measures scenario" is estimated to be relatively slight, whereas in the second scenario it amounts to about 50 %.

The not inconsiderable range of expert judgements on the impacts of single measures or packages of measures in the "small-consumer sector" in Germany is further burdened by a very meagre data basis on the structure of the useful energy demand in the individual subsectors. Assumptions on the energy technology structure of the respective subsector frequently have to be made on the basis of individual cases concerning companies, buildings or institutions. The IKARUS database (Laue et al. 1997) can now provide assistance here, but the statistically validated representativeness achieved by broad-based surveys as performed in the USA every three years at an expense of US$ 4 million is not available for Germany and many other industrialized countries. However, if the technical structure is not adequately known then empirical impact analyses in these countries are faced with the problem of a very unreliable extrapolation from the effects of climate policy measures observed from specific cases. This unreliable initial data position for the small-scale consumer sector leads to the respective CO_2-mitigating impact of individual measures or packages of measures being regarded as an educated guess rather than a quantitative forecast which, in essence, could not be unambiguously "derived".

In order not to run the risk of the unverifiable arbitrariness of the educated guess process, the basic assumptions will have to be made transparent and reconstructible. Through revisions and updatings, this documentation takes on the form of empirical knowledge which could ultimately be processed in expert systems and would thus be available more rapidly in future for ex ante evaluations. The first steps in this direction can be perceived in the MURE database (cf. ISIS et al. 1997).

3.4.4 Households

3.4.4.1 Space heat

Remarks on quantifiability

Measures in the building sector comprise a broad spectrum ranging from information, advice and tax concessions through investment subsidies to laws and ordinances. It is only possible to quantify impacts on CO_2 emissions, i.e. achievable savings in tonnes per year, for some of these measures. However, this is not so much a methodological problem as rather a question of the available data. In contrast, other measures cannot be quantified at all. The lower the intervention intensity of a measure, the greater is the leeway of the private households and the more difficult is it to assess the impacts of such measures. The measures under consideration are generally divided into the following two main categories:

- *Unquantifiable* measures are usually those of a qualitative nature such as public relations (information, motivation) pursuading the consumer save energy. This may also include such measures aimed at reducing statutory, administrative or other target-group-specific obstacles where it is difficult, or perhaps even impossible, to determine the assignable fraction of energy savings results with adequate certainty. Due to the large number of factors influencing the reaction of those affected, the influence of specific measures can hardly be isolated. In these cases, only a qualitative assessment of the measures' impacts can be performed at most.

- *Quantifiable* measures are those in which with the aid of empirical impact analyses from the literature, with plausible and consistent assumptions, as well as other appropriate data and information sources, the achievable CO_2 reduction can be calculated with generally adequate accuracy either model-exogenously or with the aid of models. In general, impacts are quantifiable for those measures which can be described by means of technical variables, as for example in certain ordinances and standards, as well as funding programmes which can be expressed in energy-technology improvements and monetary values.

Model-exogenous calculations and estimates

The CO_2 savings achievable by a measure depend on a wide variety of economic and technical parameters. Due to a lack of detailed data and information it is not always possible to cover all determinants and perform model-based calculations. For this reason, model-exogenous calculations have been selected for some of the individual measures. For each reduction measure under consideration, empirical data are to be processed from various sources and supplemented by consistent and well-founded assumptions. The respective determinants for the achievable CO_2 savings display a considerable spread. For reasons of simplicity, weighted averages can be used for rough estimates. Due to these simplifying assumptions, the results of such calculations must be regarded as an educated guess.

In the sector of space heat for households, attention is focused on three energy-related effects or measure domains:

- improvement of thermal insulation at the external envelope of the building,
- increasing the annual utilization rate of the heat generators and
- changeover to lower-carbon fuels.

The following points must be noted in the impact analysis of measures:

- All the savings considered here refer to the space heat demand without water heaters.
- Emissions from heating with electricity are not included in the household sector but in the conversion sector.
- CO_2 savings are calculated by comparing the development with measures and without measures.
- If possible, the calculated CO_2 mitigation achieved by the individual measures implemented in a package should be added up without double counting. If overlaps occur, they are indicated separately.

A tightening up of requirements for *thermal insulation in new buildings* is considered as an example to illustrate the procedure. This involves in particular the isolated impact of the 1995 Heat Protection Ordinance (WSchV95), which in comparison to the previously valid WSchvV82 leads to a 30 % lower heat demand. Assuming that in practice the standards are just observed, the overall savings result from the specific savings and the floor space newly constructed in the period under consideration (Table 3-4). Increased emissions due to the extension of floor space were not taken into account. The purpose is merely to show how much greater the CO_2 emissions would be if from 1995 new buildings had not been insulated according to WSchV95 but rather according to the existing WSchV82.

Table 3-4

Impact of Increased Thermal Insulation in Germany WSchV95 in Comparison to WSchV82 in 2005

	unit	old federal states	new federal states	total
a new floor space up to 2005	million m^2	420	72	492
b heating requirements WSchV95	$GJ/(m^2a)$	0.306	0.306	0.306
c annual utilization rate	-	0.8	0.8	0.8
d energy consumption WSchV95	PJ/a	161	28	189
e energy consumption WSchV82	PJ/a	230	39	269
f energy savings	PJ/a	69	12	80
g specific CO_2 emissions	kt/PJ	62	60	
h CO_2 savings	million t/a	4.3	0.7	5.0
From: for a: Prognos (1995), for b: Kolmetz, Rouvel (1995). Calculation: $d = a \cdot b/c$; $e = d/(1-0.3)$; $f = e - d$; $h = f \cdot g$.				

According to WSchV95, the maxium annual heating requirements in new buildings (with an estimated average A/V ratio of 0.75) are 85 kWh/m^2 or 0.306 GJ/m^2. The assumed average annual utilization rate of the heat generators (as of 1995) of 0.80 is kept constant since the influence of improvements in the utilization rate on CO_2 savings are assigned to the Amendment to the Ordinance on Heating Facilities. The total final energy consumption of the additional heating capacities then amounts to 189 PJ/a. If the WSchV82 were still valid, this figure would be 80 PJ/a higher at 269 PJ/a. This thus leads to average specific CO_2 emissions, which essentially depend on the gas to oil ratio, of 62 kt/PJ for the federal states of the former West Germany (gas/oil: 1.7) and of

60 kt/PJ for the new federal states of the former East Germany (gas/oil: 3.0) thus bringing about a CO_2 reduction of 5 million t/a in the households sector.

Derivation of further individual measures from calculations using the IKARUS-LP model

The level of reductions in the "with additional measures scenario" is taken over from LP model calculations for the private households sector. The entire reduction of all mitigation measures in the "with additional measures scenario" in comparison to the "with measures scenario" is taken into consideration here. The IKARUS reduction scenario is taken as a basis where it is assumed that the mitigation goal for the year 2005 pursued by the Federal Government can be achieved by the interplay between all sectors. The optimal value for CO_2 mitigation in the households sector calculated by the model is transferred unchanged to the "with additional measures scenario". The LP model identifies minimum-cost fields of action for CO_2 reductions in the households sector, which can then be broken down into individual measures with the aid of further information and model-exogenous rough estimates.

3.4.4.2 Electrical appliances and water heaters

The fields of electrical appliances and water heaters in the households sector for Germany are characterized by a wealth of very detailed structural data being available to determine energy consumption.[19] However, there are restrictions in data availability for the new federal states of the former East Germany. Although differentiated data are also available here on the total inventory, nevertheless there are hardly any long time series. On the basis of this comparatively good database, the impact assessment can be performed in very great detail at least for the old federal states of the former West Ger-

[19] For example, with respect to *electrical domestic appliances* in addition to official statistics a large number of regular studies on levels of equipment and age of the appliances are available (e.g. ZVEI 1992, VDEW 1991 and 1996, eböK/TUM 1990, Prognos 1995, Geiger et al. 1993, Kolmetz et al. 1994 and 1995), there are also some detailed studies on the specific energy consumption of both average and also new appliances (e.g. eböK/TUM 1990, ebök 1997, Michael 1991 and 1993, NEI 1995, Prognos 1995, ZVEI 1992).Although the data available on *water heaters* are less differentiated, nevertheless by means of plausible allocation calculations the structure of the heating systems (for which detailed data are available) can be determined relatively effectively (e.g. Kolmetz et al. 1994 and 1995).

many. For the former East Germany, the results have to be estimated by extrapolating the results for the former West Germany.

Only those measures aimed at *new* applicances or facilities were investigated. Interventions with respect to old appliances (i.e. the inventory) were not assumed. A regulatory intervention with predefined minimum standards for the energy efficiency of the respective appliances is considered as a model for the various measures:

- A *Heating Systems Ordinance* defines minimum requirements for the efficiency of heating systems (above all oil and gas heating systems).
- In an *Ordinance on the Use of Electricity*, minimum standards are laid down for certain electrical appliances (washing machines, refrigerators and freezers, dishwashers) and components (standby circuits).

In principle, the methodology of impact analysis described in the following is also applicable for equivalent instruments, e.g. voluntary agreements by manufacturers or importers of appliances and facilities.

The *impact potential* of the respective instruments is calculated in two different ways depending on data availability:

- For those cases where historical data are available on levels of equipment and specific energy consumption, the impact potential is calculated by a *stock exchange model*.
- If structural data differentiated according to age category is not available, values *averaged over the entire appliance fleet* are used for the respective scenario sample points.

In the *stock exchange model*, the energy consumption for the respective appliance or the facility is determined according to the following equation:

$$E_i = E_{i-1} + n_{neu,i} \cdot e_i - \sum_{j=1}^{i} (n_{ges,j} \cdot k_{Abg,i,j} \cdot e_j) + \sum_{j=1}^{i} (n_{ges,j} \cdot k_{Abg,i,j} \cdot k_{Ers,i,j} \cdot e_i)$$

with

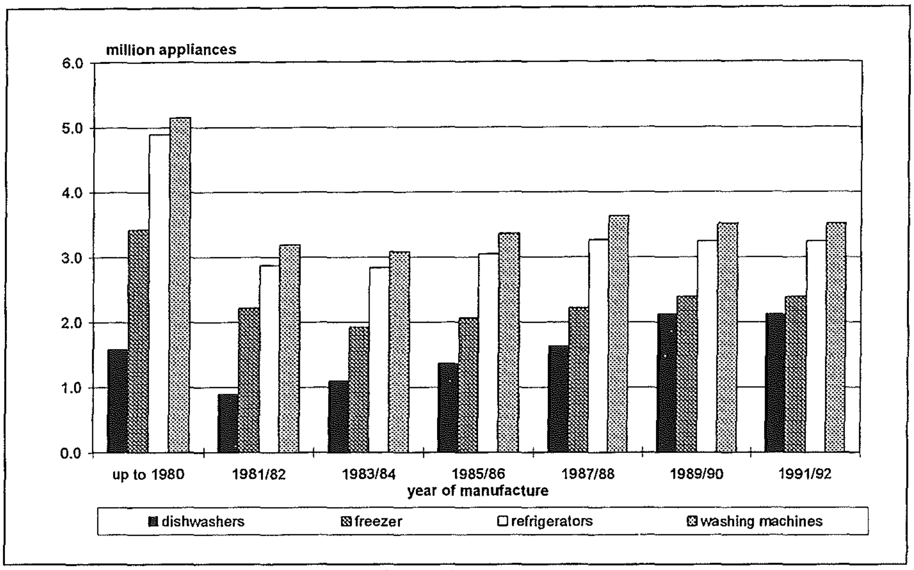
i	index of the scenario sample points
j	index of the appliance age categories
E_i	energy consumption in scenario section i
$e_{i/j}$	specific energy consumption of new devices in scenario section i and age category j
$n_{neu,i}$	net addition of devices in scenario section i
$n_{ges,j}$	total appliance inventory of age category j
$k_{Abg,i,j}$	age-related reduction rate of appliances in age category j in scenario section i
$k_{Ers,i,j}$	level of replacement of age-related appliance reduction in age category j by new appliances in scenario section i

Use can either be made here of appropriate surveys for the historical increase in facilities or simple estimates must be made. Appropriate surveys are available for large domestic appliances, i.e. washing machines, refrigerators and freezers as well as dishwashers, for the old federal states of the former West Germany (VDEW 1991 and 1996, ZVEI 1992).

The analysis of these data (Figure 3-7) shows that the average utilization time for the electrical appliance shown can be estimated at 15 years as a good approximation, although the age-related replacement rates for the individual appliances may vary. With a scenario period of 13 years (1992-2005), the equipment inventory in use in the first year will therefore be almost completely replaced by new appliances.

Figure 3-7

Age Structure for Large Domestic Appliances in Germany (Old Federal States) in 1992



From: Calculations by the Institute for Applied Ecology

Structural data of this nature are unknown for water heaters so that recourse has to be taken to mean values. It is assumed that water heaters have to be replaced roughly every 20 years for reasons of age.

Taking into consideration the increase in water heating systems in new buildings, it follows that in the year 2005 approx. 66 % of the oil water heaters and 76 % of the gas water heaters will have been newly installed after 1992. The importance of a separate consideration of these replacement processes is illustrated, for example, by the situation with water heaters in the new federal states. Since in 1992 natural gas or oil water heaters only played a minor role here, in 2005 the inventory will be absolutely dominated by new installations. The fraction of heaters installed after 1992 is therefore estimated to be 90 % (oil) and 93 % (natural gas) for the year 2005.

In addition to determining energy consumption data for the *end point* of the scenario period, calculations with the stock exchange model also identify *intermediate sample values* in the scenario period.

The impact potential for the respective instruments is determined on the basis of *mean value estimates for all the appliance fleets* by the following equation:

$$E_i = n_{ges,i} \cdot e_{mittel,i}$$

with

i	index of the scenario sample points
E_i	energy consumption in scenario section i
$e_{mittel,i}$	specific average energy consumption for all appliances in scenario section i
$n_{ges,i}$	total appliance inventory in scenario section i

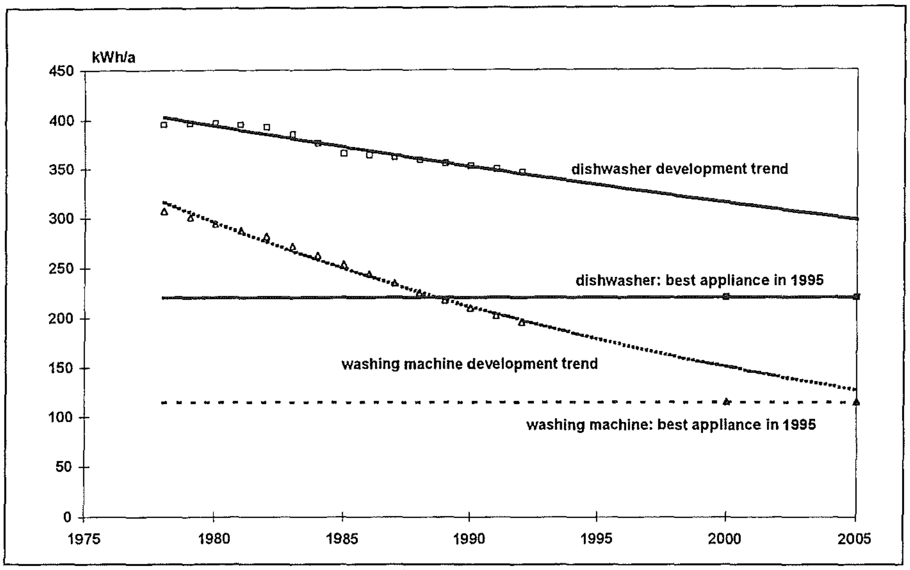
If no inventory data are available but rather data on the development dynamics of the corresponding energy application, this mean value method can naturally also be applied to values normalized for the initial value. An example of the application of such a method is to determine the energy consumption of standby circuits, for which only a total consumption is available but no application- or appliance-age-specific differentiation. This method is not difficult to apply here since in view of the rapid obsolescence of the appliances it may be assumed that in a scenario period of 10 to 15 years *all* appliances will have to be replaced at least once.

In addition to the operational area for the instruments considered, i.e. the new applicances affected during the scenario period, the *specific energy consumption* and the *specific energy savings* for the variants to be compared must be identified.

On the basis of the long time series already available, a development trend can be extrapolated for the future from the past development of *large domestic appliances*. Even if such estimates are naturally of a speculative nature and could possibly neglect (erratic) technological innovations, the analysis in Figure 3-8 shows that, at least in the past, improvements in appliance efficiency certainly followed a continuous function.

Figure 3-8

Development of the Average Consumption of New Dishwashers and Washing Machines in Germany (Old Federal States), 1978 - 2005



From: Calculations by the Institute for Applied Ecology

The figure shows by means of a concrete example the consequences of accelerating improvements in efficiency by applying additional policy instruments:

- The example of the washing machine demonstrates that the specific energy consumption shown in the reference projection is only slightly above the consumption of the best appliance in 1995 (defined by the Ordinance as a minimum standard). The major effect of the policy instrument is to accelerate the penetration of the appliance inventory by these appliances and thus to reduce fleet consumption more rapidly (2005: 11 % lower than in the reference).

- The example of the dishwasher shows that the political instrument analysed can be used to achieve an efficiency level not initially expected in the development trend as well as significantly improving fleet consumption due to the more rapid penetration (2005: 25 % lower than in the reference).

Naturally, in both cases the effect on the consumption of the overall appliance fleet is greater the more dynamic the increase in equipment rates is. Due to the high saturation level for washing machines (i.e. purchase of new appliances mainly as replacements), the change in the average fleet consumption due to a maximum consumption standard is lower than for dishwashers, where a higher increase in equipment rates can be expected.

Another possibility of determining the specific energy consumption is by increasing the efficiency of energy conversion facilities through an analysis of the development of the utilization level. The specific energy consumption for *central water heating systems* can be determined via the *levels of use resulting in the mix* or rather their difference (e.g. 7 percentage points for oil-fired water heaters, 8 percentage points for gas).

In addition to the above-mentioned possibilities of indirectly determining the savings potential, it can also be directly estimated from the literature or a comparison of prototypes and assigned to the corresponding instruments by means of normalization procedures. For standby circuits, for example, an overall savings potential of 80 % is specified, on which is superimposed an extrapolation for the total electricity consumption of TVs and video recorders in the initial year (7.3 TWh). It is assumed that the number of these applications with stand-by functions will increase by 50 % up to the end of the scenario period.

In the analysis of the described instruments there is undoubtedly a danger of *overestimating the impacts* since even without any regulations some of the newly purchased appliances or facilities would have conformed to the corresponding standards:

- Such double counts can largely be avoided by explicitly considering the efficiency improvements in the average specific consumption values for new facilities in the *stock exchange model*.

- In assessing the *mean fleet consumption*, plausible assumptions must be made on the "anyway" application of the components with the correspondingly required consumption standards. For example, in the case of standby circuits with an efficiency increase of 80 %, this fraction is conservatively estimated to be about 30 %.

Furthermore, the following points must be remembered in the impact analysis:

- *Slowdown effects or repercussions* may be expected at best indirectly with the policy instruments studied (innovation development etc.) so that they can only be considered to a limited extent in an analysis restricted to a few years.
- Since the instruments investigated are primarily aimed at the manufacturers and importers and can be checked relatively effectively, in principle a *degree of compliance* of 100 % can be assumed.
- *Synergy and overlapping effects* are not to be expected due to the sector-specific and goal-directed orientation of the policy instruments.

The *emission-side assessment* of the energy savings identified must be performed in different ways:

- The instruments aimed at direct oil and gas savings are in any case assessed fuel-specifically. The associated emission factors may therefore be directly superimposed on the corresponding energy savings.

- The electricity savings calculated only have an indirect emission impact and are included in the modelling of the power-generating units in the form of altered electricity demand. However, for *reporting purposes* these electricity savings have been assessed with a mean emission factor for the entire electricity supply in the *reference case*. There is no differentiation according to limit resources in the various load ranges.

3.4.5 Transport

3.4.5.1 Preliminary remarks

In Germany about 30 individual measures - both "implemented" as well as "additional" (measures envisaged or additionally proposed by the Federal Government) must be considered in the transport sector with respect to their possible CO_2 reduction potential.[20] As in other CO_2-relevant fields, considerable methodological problems arise with the impact analysis of individual measures in the transport sector. The various individual measures often interact with each other; the impacts may complement and reinforce each other (e.g. speed reductions, increasing the mineral oil tax, measures for stabilizing the traffic flow, setting fuel consumption limits, general training in increased energy efficiency, information campaigns), they may overlap (e.g. BVWP '92, combined transport on waterways, relocation of transit traffic from the road to rail and ship) or else neutralize each other (strengthening combined transport, relocating transit traffic to rail and ship, and expanding the rail networks and waterways on the one hand, as well as an extension of the road system and the Act on Deregulation of Wage Scales on the other). The same is incidently also true of developments and decisions in other policy fields and sectors whose impacts support CO_2 reduction efforts in the transport sector (e.g. space-saving land-use policy) or have a counterproductive influence on these measures (e.g. globalization and internationalization of industry and trade, lean production).

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[20] In decreasing order of intervention intensity by the government, they can be assigned - even if not always quite strictly - to the following categories:

- *regulatory measures*: Gas Displacement Ordinance, structural reform of the railways; Act on Deregulation of Wage Scales, reduction of maximum speed limits in road traffic, limits on fuel consumption;
- *price policy measures*: increasing the mineral oil tax, emission-related motor vehicle tax, tolls for using certain roads, raising the EU minimum rates for mineral oil tax, CO_2 emissions for new motor vehicles, tax on aviation fuel, raising the fuel price, mileage-dependent road-use tax;
- *investment-policy measures:* federal transport route plan, increasing the attractiveness of public passenger transport, influencing traffic by stabilizing the traffic flow, goods traffic centres, combined transport via waterways, railways' site conception, relocating international transit traffic from the road to rail and ship, applying modern information technology for avoiding and regulating any further increase in traffic;
- *research promotion measures:* urban traffic research programme, research promotion and information on urban traffic planning and low-emission urban transport, transport research, research programme on aviation pollution and
- *informative and other measures:* information on energy-saving and environmentally friendly transport behaviour, modification to the common rules of procedure of federal ministries, introduction of a traffic impact review, general training in increased energy efficiency.

In all individual measures, a differentiation must be made between the short-, medium- and long-term reactions on the part of road users. There will be a short-term reaction to a hefty increase in the cost of fuel - e.g. by raising the mineral oil tax - but in the medium and longer term this will probably be considerably reduced by familiarization and adaptation (e.g. redistribution of the household budget, higher income).

Furthermore, it must be noted that many individual measures are only mentioned qualitatively (e.g. urban traffic research programme) or are not quantified with respect to their characteristics (e.g. raising the EU minimum rates for mineral oil tax) and that, moreover, many individual measures are not completely implemented in the period under consideration or are realized in a different manner.

Against the background of the above-mentioned considerations, estimates of the CO_2 mitigation impacts of certain individual measures should not be misinterpreted. In view of the many imponderables and the frequently unquantifiable or indeed counterproductive impacts of individual measures, the CO_2 mitigation potential determined merely permits a rough comparison of different measures with respect to their possible contribution to CO_2 reduction. Due to the large range of interactions, the impacts of individual measures in the transport sector cannot be added up as a rule.

3.4.5.2 Impact of selected individual measures in the transport sector

The *price policy measures* investigated with a view to their CO_2 reduction potential (increasing the mineral oil tax, raising the minimum rates for the mineral oil tax, raising the fuel price, road-user fees) assume a classic market failure in the transport sector. The use of transport services causes damage (by atmospheric pollutants, noise, land use, reduction of the general quality of life) and leads to costs for third parties, which do not have to be borne by the road users themselves but rather by the general public. In the scientific community, it is undisputed that for individual and road goods transport these external costs are higher per service unit (DM per pkm or tkm) than - with the exception of air transport - other transport carriers. To this extent, the demand for higher fuel prices and an increase in the price of road traffic should create a functioning market mechanism.

The goal of all price policy measures is to create incentive mechanisms for energy savings in passenger and goods transport. These energy savings can be achieved by the following reaction possibilities:

- decrease in car ownership (passenger traffic),
- greater level of occupation (passenger traffic) and higher load factor (goods traffic) of the vehicles,
- change in the choice of means of transport (passenger and goods traffic),
- shorter journeys (passenger traffic) and shorter procurement and distribution paths and avoidance of empty runs (goods traffic),
- manufacture, procurement and use of vehicles with more efficient and lower consumption (passenger and goods transport),
- avoidance of traffic (passenger and goods transport) as well as
- in general more awareness of energy consumption (passenger and goods transport).

The impact of price-policy instruments essentially depends on the form of the measures. For example, if fuel prices are to rise to DM 3 per litre (petrol and diesel) this must be performed in a continuous and stepwise manner. In order to ensure an impact on traffic, corresponding rises must also be made in the other EU countries to prevent fuel tourism.

The CO_2 mitigation effect of this measure quantified in passenger and goods transport (of 23 million t in comparison to the reference development by Prognos up to 2005) was determined - in spite of many methodological reservations - via certain assumptions on the price elasticity of demand. In the literature values of -0.1 to -0.7 can be found. With the value of -0.25 assumed here, for example, a price increase of 50 % in real terms leads to an approximately 13 % reduction in mileage. It must be noted that the percentage mitigation effects in goods transport (-5 %) are considerably below those in passenger traffic (-12 %).

Transport companies can in general make their fleet operation more efficient (such as higher load factors, lower proportion of empty runs, improved logistics) and can pass on the increased transport costs for example to the forwarders. The latter can then also rationalize their production, procurement and distribution logistics, choose different means of transport or pass the increased transport costs on to their customers. In short-distance road transport the reactions - due to the lack of adequate alternatives - are very much more inelastic than in long-distance transport.

In contrast to mineral oil, CO_2, energy or motor vehicle taxes, road pricing as a function of mileage permits a direct control of the transport demand via the price to be paid. Since road pricing is directly linked to the mileage, route segments, journey lengths and/or destinations, the motorized traffic can be influenced by a corresponding tax level so that the desired "target traffic volume" is established.

From the perspective of CO_2 reduction, road pricing must be applied to all categories of road. Fees restricted in time, region and/or route segment may by all means be meaningful to mitigate local environmental pollution, however, they imply the danger of being avoided or bypassed with possible counterproductive impacts on mileage, fuel consumption and thus also on CO_2 emissions.

The impacts of road pricing (DM 0.10 per passenger car/km; DM 0.20 per goods vehicle/km) will be determined in a similar manner to an increase in the fuel price. Relative to the filling station tax prices, this charge would correspond to a fuel price of DM 2.60 per litre of petrol and DM 2.45 per litre of diesel. Energy savings would result from

- lower level of car ownership,
- increased level of occupation and load factors,
- reduction of journey distances,
- route optimization,
- modification of the modal split,
- avoidance of journeys as well as indirectly
- via more awareness of energy consumption and
- the manufacture, procurement and use of more energy-efficient vehicles.

The CO_2 mitigation potential (about 15 million t) cannot be exploited up to the year 2005 due to a current lack of technical facilities and corresponding legal (data protection) conditions. Although, due to the opportunities of direct steering and control road pricing is basically preferable to an increase in the mineral oil tax, the latter has the advantage of relatively simple implementation under the given boundary conditions and an immediate increase in revenue for the government budget.

The presetting of fuel consumption limits, in addition to the definition of CO_2 limits (e.g. 90 g CO_2/km), is the simplest and most direct way of achieving certain quantitative CO_2 mitigation targets. Limits of this type are really only meaningful for newly licensed vehicles. From the wide range of possibilities for legal and administrative regulations of this type, the case is considered where the average consumption (litres per hundred km) of all passenger cars newly licensed in Germany would from now on have to be reduced by 5 %, relative to the consumption reflected on average in realistic driving cycles (test consumption values). These mitigation rates are valid both for petrol and diesel vehicles. The average reduction in consumption determined for 2005 for the passenger car inventory (for petrol vehicles from 9.2 to 7.8 litres per hundred km and for diesel vehicles from 7.5 to 6.4 litres per hundred km) and the identified CO_2 mitigation of 11.3 million t can be achieved under the following conditions:

- average age of vehicles at deregistration 11 years,
- constant development of the passenger car fleet,
- constant structure of the passenger car fleet according to cubic capacity classes,
- constant ratio of petrol to diesel vehicles, and
- unchanged mileage.

However, this will require administration costs for increased control and monitoring measures.

Of the *regulatory measures*, particular emphasis must be given to a reduction of the maximum speed limits permitted for road traffic (100, 120 and 130 kph: motorways; 80 kph: other roads outside built-up areas) with respect to the level of the CO_2 mitigation effect. A general reduction of the maximum permitted speed limit (100/80 kph) would lead to a smoother traffic flow and fuel savings, both of which would have a direct CO_2-mitigating effect.

The basis for calculating potential savings in private motorized traffic by means of speed limits is the distribution of speeds for a state corresponding to the previous maximum speed regulations and distributions of speeds after the introduction of lower speed limits.

The respective mileage and the associated average consumption for classes of mean driving speeds are specified in these distributions. The speed distributions were initially estimated separately for the old and new federal states, for cars with petrol and diesel engines as well as for motorways and other roads outside built-up areas on the basis of existing studies, traffic surveys and censuses. The potential mitigation can be derived by linking the average consumption per speed class to the distribution of the passenger car inventory between the speed classes.

Heavy goods traffic is not affected by this measure in the first instance. However, speed measurements by the Federal Highways Research Institute (BaSt) show that more than half of the larger heavy goods vehicles exceed the currently prescribed speed limit of 80 kph on motorways. The average driving speed on free sections of the motorway was, for example, about 87 kph in 1992. Since a general compliance level of 80 % with the maximum speed limits for passenger cars is assumed, which will be achieved by increased monitoring and control measures, it is certain that part of the "dormant" potential in road goods traffic can be tapped.

A contribution to CO_2 reduction by a speed limit of 100 kph on motorways and 80 kph on other roads outside built-up areas of 12.5 million tonnes (2005 relative to the Prognos reference case) is probably a rather conservative estimate since it was assumed that the mileage remains constant. In fact, it will probably tend to be reduced. A restriction of the permissible maximum speed on motorways at a higher level (120 kph or 130 kph) would, under otherwise unchanged conditions, naturally lead to lower reduction volumes.

Reductions in the maximum speed limits generally have the advantage that - apart from increased monitoring and new traffic signs - they would only represent a slight burden on the federal budget, could be implemented immediately and above all would have an immediate impact.

3.4.5.3 Impacts of packages of measures in passenger and goods transport

A policy aimed at reducing CO_2 emissions within the regulatory framework of a free market economy should in the transport sector work towards

- using more environmentally acceptable means of transport,
- reducing transport/traffic requirements,
- decreasing the specific energy demand and the resulting specific CO_2 emissions.

The following components could form the centrepiece of a target-oriented CO_2 reduction strategy:

- raising the EU minimum rates for mineral oil tax (fuel price DM 2 per litre for petrol and diesel),
- CO_2 emissions for new motor vehicles (conversion of motor vehicle tax),
- taxation of aviation fuels (application of the mineral oil tax) and abolishing the exemption from value added tax for transboundary air traffic,
- reducing maximum speed limits on the road (motorways: 120 kph; (other roads) outside built-up areas: 80 kph; in built-up areas: unchanged).

In view of the problems of time and content involved in the political implementation of even one measure at the national or European level, such an overall strategy, which would have to be adopted and implemented without delay to achieve perceptible CO_2 reductions in 2005 (40 million t CO_2 - stabilization at the 1990 level), must, however, be regarded as unrealistic.

Existing studies on the efficiency of packages of measures have been evaluated to investigate a "more realistic" strategy concept for mitigating Co_2 emissions in the transport sector (Delphi, expert judgements, interviews and surveys, hierarchically ordered impact analysis of the individual measures contained in the package of measures, factor analysis, econometric model calculations etc.). This concept proceeds from the basic assumption that acceptance of the measures applied (and thus at the same time their effectiveness) greatly depends on overall economic development being as little inhibited as possible and the strategy being socially balanced. Solely imposing charges or obstructing passenger vehicles and heavy goods vehicles as the most significant groups of CO_2 emitters without, at the same time, providing any appreciable improvement in alternative means of transport would be regarded as victimization and would at the same time lead to considerable disturbances in the workings of the economy and the course of life.

An integrated transport and environment policy can most easily be implemented by a balanced mix of many different individual measures. What is important is an overall transport and environmental concept in which individual measures do not have a counterproductive impact on each other. [21]

In all available studies, the spectrum of measures (up to about 100 individual measures) primarily covers the fields of regulatory policy, price policy (financial policy), investment policy (infrastructure policy) and land-use policy. If meaningfully complemented by organizational measures, expanded public relations (advertising campaigns for environmentally acceptable behaviour and for the use of environmentally friendly means of transport), a selective technology policy (increasing the energy efficiency of vehicles, transport and operating systems) as well as comprehensive training in more environmentally friendly modes of driving, packages of measures comprehensively compiled could bring about considerable CO_2 mitigation.

In view of the short implementation period, such a strategic programme could "only" tap a reduction potential of about 30 million t of CO_2 by 2005 (-13 % in comparison to the Prognos 2005 "reference case"); however, in the longer term CO_2 mitigation would be remarkable. Due to the large number of harmonized individual measures, such a strategy would have the advantage that it would be easier to implement. The individual measures are less prominent in this strategy (proportioned) and can therefore more easily achieve consensus and since they mainly concern the national level a tedious process of mutual consent at the European level can be dispensed with or is less difficult. However, such a concept also includes the federal states and the local authorities (e.g. in managing car parking areas) to a greater extent, with the land-use policy "on the spot" receiving more weight than has previously been the case from the aspect of traffic reduction.

[21] On several occasions, the DIW has already been involved in defining and formulating overall strategies of this type to mitigate the negative impacts of traffic. In its study on measures for the transport sector, Prognos (1991) has also drawn attention to the fact that only a meaningful compilation of packages of measures can indicate the actual scope for CO_2 reduction and therefore the individual measures examined should be grouped in scenarios of measures. (The "incentives" scenario leads to a CO_2 reduction of 20 % in 2005 in contrast to the trend; the "rules" scenario to a 46 % reduction).

3.5 Combining Sectoral Estimates Into Overall Scenarios

In collating the - initially partially derived - sectoral estimates into scenarios for the entire energy economy, the major concern is to combine sector-specific and cross-sectoral measures and their impacts to form a consistent picture of developments in the energy economy. Particular attention must be paid iteratively to the interdependences between the final-consumer sectors and the conversion sector.

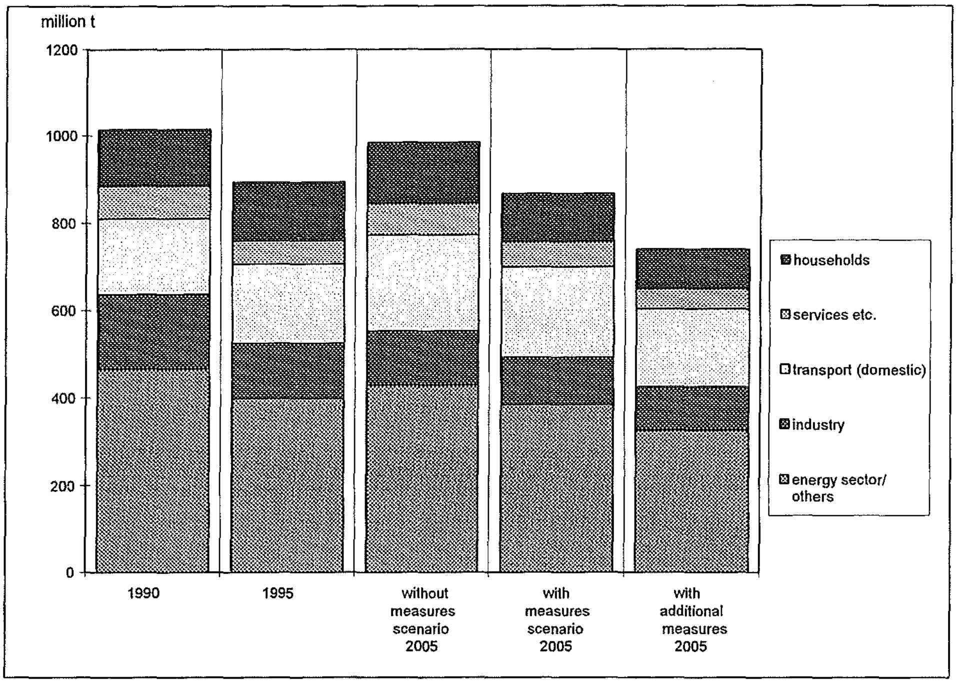
Giving particular consideration to these interactions, the most important results of the scenarios investigated for Germany can be outlined as follows (Ziesing et al. 1997, cf. also Figures 3-9 and 3-10):

- In the "without measures scenario" the CO_2 emissions in 2005 would be about 3 % lower than in 1990. Substantial emission mitigation in industry would be balanced against just as significant emission increases in the transport sector.

- In the "with measures scenario" CO_2 emissions in 2005 would be 14.5 % lower than in 1990. This involves an above-average emission mitigation in industry and the energy sector. However, emissions are also perceptibly reduced for small-scale consumers and in private households. Nevertheless, in the transport sector a further increase of CO_2 emissions must still be expected; in 2005 they would probably be one fifth higher than the 1990 level.
- The "with additional measures scenario" results in CO_2 emissions being almost 27 % lower in 2005 than in 1990. The Federal Government's goal thus also proves to be achievable in principle. Particularly substantial contributions towards achieving this goal are expected from industry, the power industry and private households. Power stations make a contribution of 28 % to the absolute mitigation of CO_2 emissions in the period from 1990 to 2005, industry 26 %, households 14 % and small-scale consumers almost 11 %. In this scenario, only a slight rise in emissions in comparison to 1990 results in the traffic sector.

Figure 3-9

CO_2 Emissions in Germany up to 2005 in the Three Scenarios



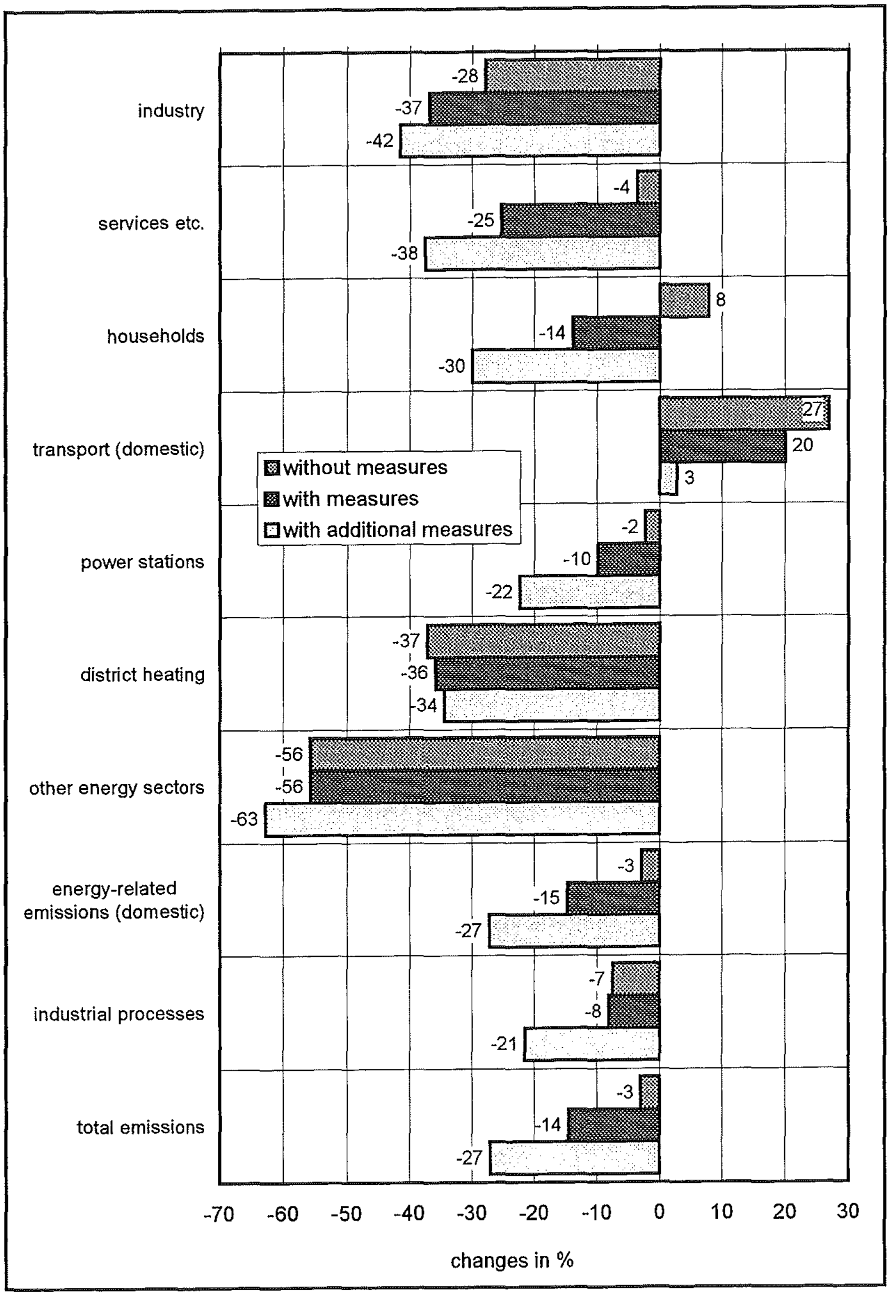
A cross-comparison of the scenarios for 2005 presents the following picture of the impacts of the measures:

- In the "with measures scenario" the CO_2 emissions are about 12 % lower than in the "without measures scenario". Particularly high absolute contributions to this reduction are made by households and the electricity generation sector; however, the contributions from the other final-energy sectors of small-scale consumers, industry and transport are also of significance.

- In the "with additional measures scenario" CO_2 emissions are reduced by a further 14 % in comparison to the "with measures scenario". Contributions to this additional mitigation are primarily made by the energy sector, transport and households.

Figure 3-10

Relative Changes of CO_2 Emissions in Germany from 1990 to 2005 in the Three Scenarios



The major findings from the scenario analysis is that a realization of the reduction goal cannot only be based on a few measures - this would necessarily lead to excessive interventions in the sectors affected - but rather requires the application of complex packages of measures in all sectors. However, central significance for achieving the reduction goal is attached to the time aspect. Only if the necessary measures and packages of measures are applied without delay is there a chance that, in view of the brief time horizon up to 2005, the goal may be reached.

4 Conclusions

Measures concerning energy and environmental policy are generally required for two reasons:

- On the one hand, energy consumption causes external costs, due to environmental pollution, long-term climate change and the exploitation of nonrenewable resources, which are not included in the price of energy and therefore, from the perspective of the overall economy, lead to a suboptimal use of resources.

- On the other hand, in energy generation and energy consumption there is a profitable potential for energy savings and substitution which is not realized due to the wide range of obstacles and market inadequacies meaning that not only investments but also organizational and behavioural changes are unexploited.

Impact analyses of policy measures for climate protection are required in order to assess the success of the previous climate protection policy so that - relative to a defined goal - the need for further action with respect to policy can be justified and a suitable combination of measures proposed. Impact analyses are also an integral part of the national reporting obligations of Annex I parties to the FCCC.

Attention is focused on the impacts of climate protection measures on energy consumption and the emissions of greenhouse gases thus arising. This firstly concerns the assessment of the effectiveness of individual policy measures and secondly the quantification of the extent to which the climate policy goal has been achieved in policy scenarios in the sense of *qualified* forecasts. In evaluating the policy options, the economic and social consequences must also be considered in principle.

Basic methodological problems

Methodological problems with impact analyses are encountered above all in the following fields:

- The impacts of policy measures or packages of measures are frequently difficult to empirically isolate from other influential factors and allocate unambiguously to certain actors (e.g. EU, Federal Government, federal states, local authorities, associations, companies).

- As yet it has not been possible to gather any experience with the application of some instruments (e.g. energy taxes, trading with CO_2 emission certificates, green price rates, cooperative procurement) in the respective national context.

- The effects of recent instruments (e.g. environmental investment fund with tax-free distribution of dividends in the Netherlands) or packages of measures in other countries (e.g. the American electric motor efficiency programme) are only transferable to a limited extent or with great uncertainties due to different national boundary conditions.

- On the basis of substitutive or complementary cause and effect relationships between individual measures, the impacts of measure combinations or programmes cannot simply be evaluated as the sum of the individual effects.

- It is particularly difficult to assess qualitative measures, which usually only directly influence investment or organizational decisions (e.g. motivation, advice, training), but may possibly be essential for the widespread impact of another measure (e.g. of directives, financial incentives).

The reports by the parties to the FCCC available as yet are based on different methodological approaches. An analysis of the first National Reports by 25 parties shows great differences in an international comparison with respect to depth of information, the quantification of emission reduction potentials and their breakdown according to sector or individual measures, the study period and the initial data. Categorization into "implemented" and "planned" measures is uneven. Upstream emissions, e.g. from imports of electricity, are rarely taken into consideration and only in a few cases are reduction effects resulting from changes in behaviour or from CO_2 and energy taxes identified. Methods of assessing the impacts of measures are frequently not transparent and there is often a lack of information on the models used. The results of the National Reports are therefore only comparable to a limited extent.

The contribution of computer-assisted models

In model-assisted scenario analysis, a differentiation must be made between simulation and optimization models. Whereas with simulation models changes in parameters (e.g. prices) with respect to certain targets (e.g. energy consumption, emissions) are calculated on the basis of reaction functions, optimization models serve to determine (mainly technology-related) activity vectors (e.g. power plant structure and application) for given targets and other restrictions.

An appropriate interpretation of model results assumes knowledge of the methodological bases and issues of model formulation. Particular attention must also be paid to the mechanisms endogenously simulated in the model and the variables and boundary conditions exogenously predefined for the model. Of no less importance is precise knowledge of the empirical database and model assumptions on the future development of technology, costs, economic structure and behaviour.

However, there is no model which adequately simulates all interactions relevant for the impact analysis of policy measures. Interdisciplinary expert knowledge and systems-analysis scenario approaches are necessary.

Combined approach for deriving policy scenarios

Within the framework of a combined approach for deriving policy scenarios, an optimization model (IKARUS) was applied particularly with respect to the question of the (energy-technology) fields of action which should be given priority for a further mitigation of emissions in Germany from the cost aspect. On this basis, the energy- and emission-related impacts of corresponding policy measures have been quantified within the framework of sectoral expert judgements and incorporated in an over-arching scenario analysis.

Stages in the impact analysis and scenario comparison

A sectoral consideration is recommended for detailed impact assessments since many of the measures to be analysed are either aimed directly at certain sectors (or technology lines such as combined heat and power generation, wind energy) or at least display sector-specific impact mechanisms. Furthermore, data availability also differs from sector to sector. The sectoral impact assessments performed at the expert level are roughly oriented towards the following analytical steps:

1. definition, classification and most precise possible description of the measure or packages of measures,
2. assessment of primary impacts (impacts on those directly affected by the measure, e.g. investors and energy consumers),
3. assessment of secondary impacts (repercussions, bandwagon effects etc.),
4. assessment of technical measures initiated (e.g. construction of plants or organizational changes),
5. calculation of impacts on the energy economy (e.g. energy efficiency and substitution effects),
6. calculation of impacts on emissions and
7. as far as possible further (qualitative) assessments of the measure according to environmental and overall criteria as well as social aspects.

The at first partially derived results of sectoral analysis are transformed into "policy scenarios" in an iterative procedure. This involves, on the one hand, the combination of effects in the final-energy sectors on the conversion sector (and thus on primary energy consumption) and its emissions, and, on the other hand, any corrections possibly necessary if the boundary conditions are violated (e.g. too high natural gas requirements) as well as the consistent harmonization of impact assessments between different sectors and complementary estimates of intersectoral synergy effects (training, motivation in the small-consumer sector on the behaviour of private households).

On the basis of national reporting requirements, three scenarios are differentiated: a hypothetical "without measures scenario", a "with measures scenario", corresponding to a reference development, and a "with additional measures scenario", which could enable the climate policy goal to be achieved.

In interpreting the results of such scenario analyses it must generally be remembered that the information content of quantitative analyses decisively depends on the quality of the data on which they are based. In analyses of future developments in the energy economy, the technical parameters, cost variables and general data of relevance for the energy requirements of the overall economic and demographic development always involve uncertainties which increase with the breadth of the analysis horizon. Furthermore, in the course of time the direct impacts of policy measures subside whereas indirect effects, which, however, can only be estimated with great uncertainties, rather tend to increase. This is particularly true of the longer-term impacts on technical progress, market development and life style. On the other hand, in a longer-term consideration greater changes of the energy system can be basically taken into consideration for technical, socioeconomic and political reasons than in an analysis restricted to a few years.

Policy-related conclusions

An important result of the scenario analysis of the impacts of climate protection measures implemented for Germany is that, for reasons of effectiveness, climate policy must not be restricted to a few measures but requires complex packages of measures in all sectors.

A perceptible contribution of the measures implemented so far for the mitigation of emissions can be seen from the comparison of the "with measures scenario" and "without measures scenario". However, other packages of measures are required to achieve the goal set. The "with additional measures scenario" demonstrates that it would be possible to reduce CO_2 emissions in Germany by about 25 % in comparison to 1990 by the year 2005. However, such additional measures would have to be implemented without delay so that the reduction could be realized in the envisaged period.

Nationally and internationally, policy for climate protection is a continuous process whose future course still remains open. For this reason, scenario analyses for assessing efforts by the various actors can only represent snapshots, which do not provide a conclusive judgement, but only give indications of the path which should be taken for climate protection.

Against this background, in spite of some problems in quantifying and assigning policy effects, impact analyses should be regularly performed in future for climate protection measures. This primarily involves the evaluation of national mitigation programmes in comparison to the goals, where the gaps identified should be closed in "with additional measures scenarios" - giving consideration to all actors - and longer-term perspectives included in the analysis. With respect to the international assessment of impact analyses for climate protection policy, particular attention must be paid to the transparency and comparability of the analyses.

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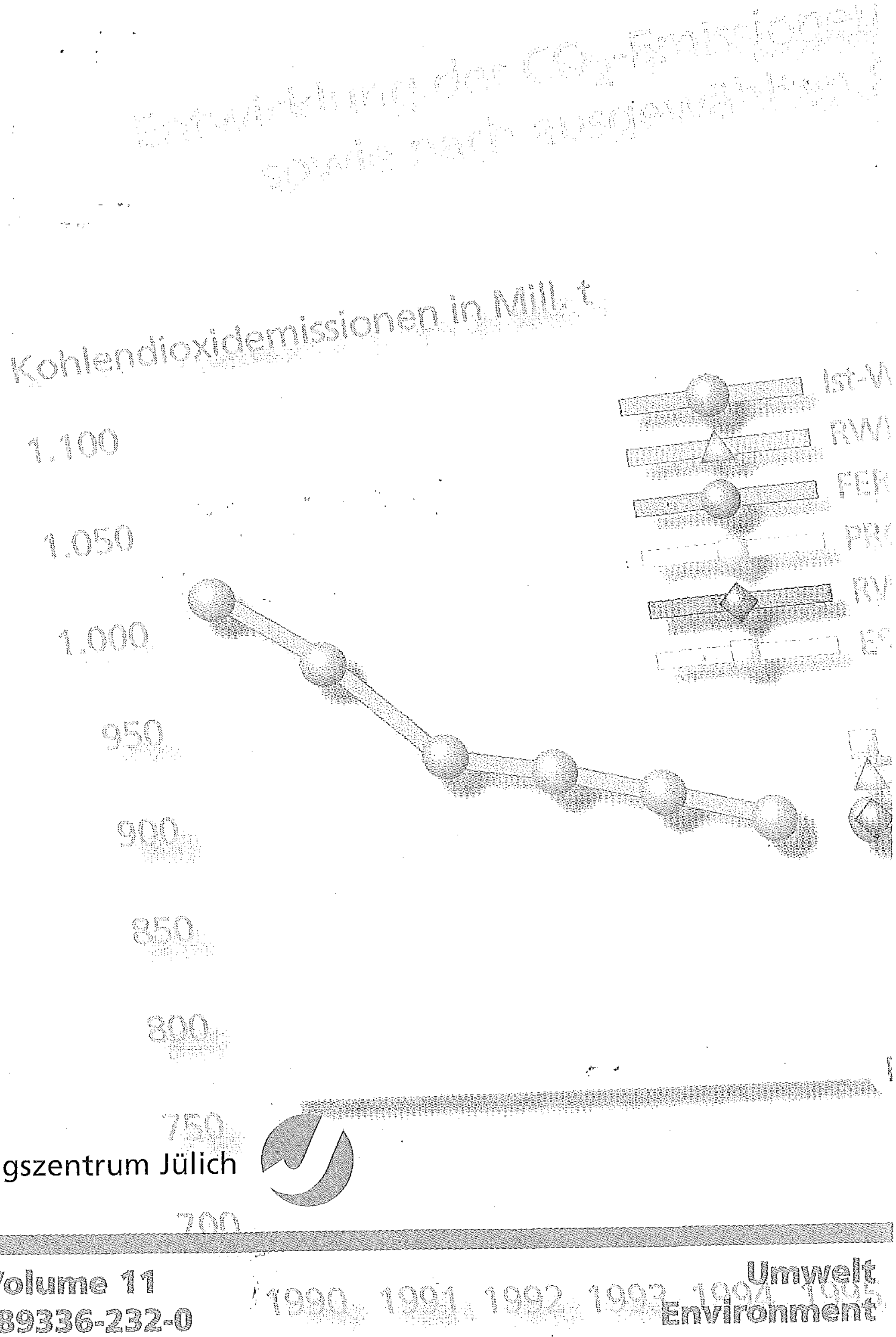

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