Impact of energy and climate policies until 2030 – a detailed bottom-up modelling approach

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ABSTRACT

In order to develop scenarios for energy requirements and greenhouse gas emissions in Germany until 2030, different sector-specific model analyses were used which were compiled into a consistent and complete quantity structure which is fully compatible with the German greenhouse gas inventories. The specific analyses which have been made in relation to space heating and hot water in residential and non-residential buildings, electrical devices in the residential and tertiary sector and industry are described in detail. In order to get a full picture of the development of greenhouse gas emissions in Germany until 2030, the results are shortly described, too. For the overall greenhouse gas emissions, in the reference scenario a reduction of 178 Mt CO_2 eq., or 17.8 %, results for the period 2005 to 2030. For an ambitious Structural Change Scenario, the reduction in emissions totals around 49 % from 2005 to 2030. The impact evaluation of existing and planned or possible energy and climate policy measures has shown that clear prospects for the necessary investments in these fields, with clear statements regarding the future incentive signals and frameworks, play a crucial role.

Introduction

Since the mid 1990s, a consortium of German research institutes[1] has repeatedly carried out scenario calculations for the development of greenhouse gas emissions in Germany on behalf of the Federal Environmental Agency (UBA). In the projects, which were published under the title "Policy scenarios for climate projection I – V", a model-based scenario approach was combined with a detailed assessment of individual climate and energy policies which have been introduced in Germany since the beginning of the 1990s.

Though the scenario calculations were carried out by a consortium of independent research institutes and thus do not reflect an official governmental view, the results of these studies have regularly been considered for national climate policies, as e.g. the Integrated Climate and Energy Policy

[1] Öko-Institut, DIW Berlin, Forschungszentrum Jülich (IEF-STE), Fraunhofer ISI (FhG-ISI) and Dr. Ziesing (independent researcher)

Programme (IECP) of the Federal Government from 2007[2], and for international reporting obligations, as e.g. the European Community's greenhouse gas monitoring.

In the following, the methodological approach and the main results of the latest policy scenario project (Öko-Institut et al. 2009) are presented.

Methodological Approach

For the "Policy scenarios for climate protection V" project (Öko-Institut et al. 2009), scenarios were created for the development of greenhouse gas emissions in Germany for the period between 2005 and 2030:

- A *With Measures Scenario (WMS)* in which the climate and energy policy measures in the different sectors which were introduced or significantly altered in the period from 2000 to 2007 (for some cases also in 2008) are taken into account, and which is accorded a high degree of prognostic relevance.
- A S*tructural Change Scenario (SCS)* in which the effect of further climate and energy policy instruments are taken into account for the development of the scenario.

For the scenario analyses, a detailed assessment was made of the respective climate and energy policy measures with regard to their effect on the development of German greenhouse gas emissions. Here, the emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6), the greenhouse gases covered by the Kyoto Protocol for the energy, industrial processes, product utilisation, agriculture and waste management source sectors, were taken into account. The source area of land use change and forestry was not taken into account in the analyses.

In order to develop the scenarios, different sector-specific model analyses were used which were compiled into a consistent and complete quantity structure for energy requirements and the greenhouse gas emissions. Specific studies are made in relation to space heating and hot water in residential and non-residential buildings, electrical devices in the residential and tertiary sector, industry, transport, power generation from renewable energy sources and fossil power generation, and for the transient emissions in the energy sector, process-related CO_2, CH_4 and N_2O emissions. For selected other source areas (HFC, PFC and SF_6 emissions and agriculture), the results of other studies were adopted or processed. For integration purposes and to determine emissions, a system integration module and an emission calculation model are used with the aid of which the detailed sector results are compressed into a quantity structure which is fully compatible with the German greenhouse gas inventories.

The detailed structure of the complex modeling approach, which is a combination of several sector specific bottom-up models for the different end-use sectors and the transformation sector, is shown in Figure 1. The main focus of this paper is on the building sector and on industry, which will be described in detail, both with regard to the development of energy consumption and CO_2 emissions in the two scenarios until 2030 and to the impact of energy and climate policy measures in these sectors. In order to give a full picture of the development of energy and CO_2 emissions in Germany until 2030, the complete scenario results are shortly described, too.

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[2] http://www.bmu.de/klimaschutz/nationale_klimapolitik/doc/44497.php

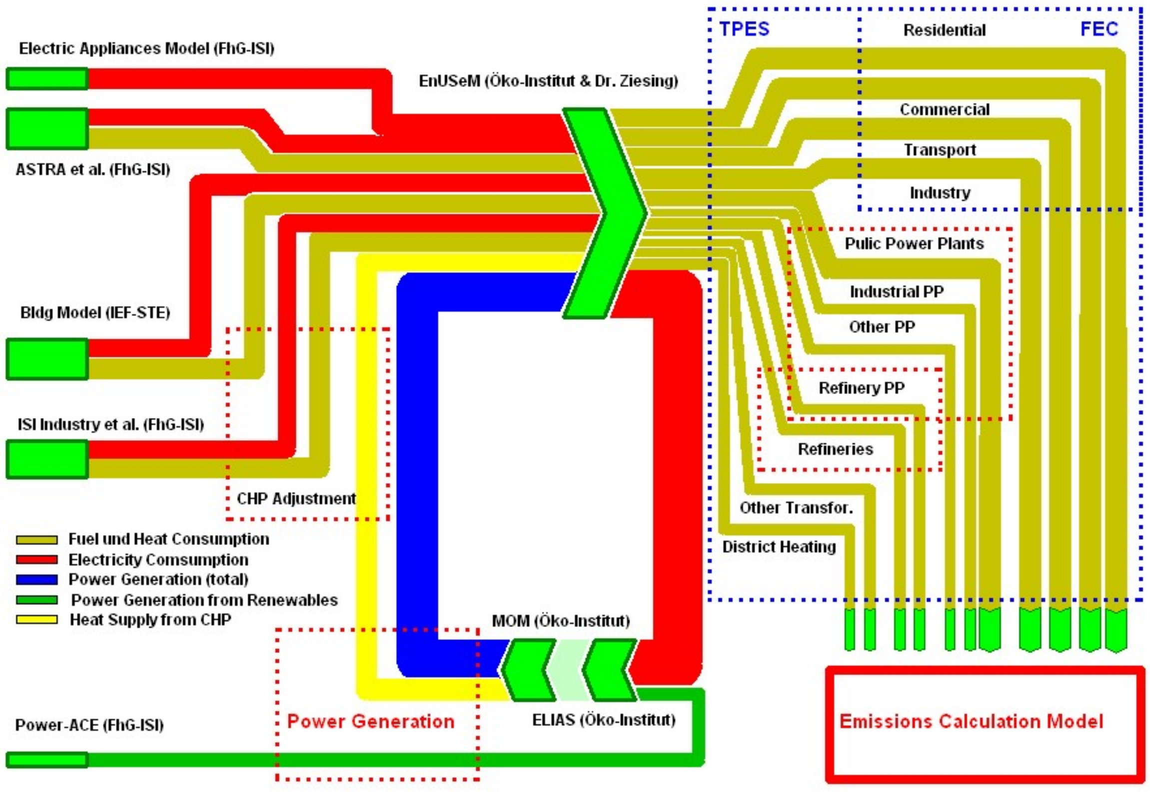

Figure 1. Overview of the modeling approach for the analysis of energy-related greenhouse gas emissions

Framework Data

A series of important frameworks plays a decisive role in developing the energy requirement and emission scenarios. This relates both to the demographic and economic framework data and the development of the energy prices. Table 1shows the most important framework data for the projection in summary.

The scenario development is based on a demographic development in which the German resident population reaches its highest level between 2005 and 2010 and decreases slightly in the following years, so that for 2020, the number of inhabitants is forecast as being 81.3 million. Even so, by 2030, the number of private households will increase slightly due to the sustained trend towards smaller households.

	2005	2010	2015	2020	2025	2030
Demographic development						
Resident population (1,000 residents)	82,438	82,039	81,790	81,328	80,670	79,750
Private households (1,000 households)	39,178	40,108	40,629	41,185	41,461	41,701
Economic development						
Gross national product (billion €)	2,241	2,483	2,701	2,925	3,151	3,377
Gross value of the processing industry (billion €)	455	521	563	606	652	697
Employees in the processing industry (1,000 employees)	7,506	7,476	7,291	7,080	6,786	6,508
Employees in the service sector (1,000 employees)	27,265	27,866	27,534	27,101	26,356	25,634
Primary energy source prices						
Crude oil (€/t)	314	299	306	338	362	389
Hard coal (€/t coal equivalent)	65	78	79	85	90	95
CO_2 certification prices (€/EUA)	18	20	25	30	33	35
Note: All price and value added figures have been adjusted. The price basis is 2005.						

Table 1: Selected demographic and economic framework data, 2005-2030

For the economic development, a relatively constant growth is assumed until 2030, so that the level of the German gross national product lies at around 51 % above that of the year 2005. The gross value in the processing industry increases at a slightly greater rate during the same period by 53 %. In relation to the employment structure, it is assumed that the level of employment in the processing industry will be around 13 % below that of 2005, corresponding to a decrease of almost one million employees. With regard to private and public services, a slight growth in the number of employees is anticipated by 2015 of around 270,000; however, by 2030, the number of employees will also decrease here to a level of around 6 % below the totals for 2005.[3]

With regard to the development of the primary energy prices, the scenarios are based on a crude oil price of approx. €389 per tonne for 2030. This corresponds to a price increase of around 24% over 2005, taking inflation into account. For hard coal, a similar dynamic is assumed as for the development of crude oil prices in the long term. Imported hard coal is accordingly around 47 % more expensive in 2030 than in 2005 (this high rate of increase results above all from the exceptionally low price level during 2005, which occurred for different reasons; the anticipated price level for 2030 however is well in line with the connection between oil and coal price development over many years). With regard to the prices for EU emission allowances, the scenarios are based on a slight price increase from 2010, which in 2030 will reach a level of €35 per EUA.

Scenario Calculations by Sector

In the following, the scenario calculations for the building sector and industry are described in detail. Sector specific bottom-up models are used to assess the impact of several policy measures in both scenarios. The quantification of the impact is mainly based on model calculations. If evaluations are available from already implemented policies, the data and results of these evaluations have been taken into account, too.

Residential and non-residential buildings (space heating and hot water)

In the *With Measures Scenario (WMS)* in buildings, which serves as a reference scenario, the building model of IEF-STE takes into account those policy measures which became effective by May 2008 or were at least approved within the framework of the German Integrated Energy and Climate Programme (BMU 2007) until June2008. The implementation of the S*tructural Change Scenario (SCS)* requires additional measures to achieve further substantial emission reductions. These measures aim at improving efficiency significantly, at enforcing the use of renewable energies and at intensifying public relations work, consulting services, training and proactive quality improvements. Quantifiable measures with respect to the impact of reduced emissions are funding programmes on the one hand and regulatory instruments on the other hand. The other measures are characterized as soft and not quantifiable instruments due to their high uncertainties (see Table 2).

Among the funding programmes for private households, the KfW programme for energy-efficient modernization and the market incentives programme for renewable energies contribute most to the *With Measures Scenario*, saving 12.1 Mt and an overall 8.0 Mt of CO_2, respectively. In the *Structural Change Scenario*, the stricter application of the Energy Savings Directive (EnEV) with 9.1 million tonnes of CO_2 and the tightening up of retrofitting requirements with 7.3 Mt of CO_2 will make the greatest individual contributions up to 2030. It is estimated that a further 5.8 and 5.9 Mt of CO_2 can be saved by means of heat contracting and by cutting the rate of value-added tax levied on products and services in connection with the modernization of old buildings to 7%.

The emission savings in the residential building sector in the two scenarios are shown in Table 3. The measures analyzed in the *With Measures Scenario* will reduce greenhouse gas emissions by about 14 Mt of CO_2 to 102 Mt of CO_2 between 2005 and 2020 and by a further approx. 15 Mt of CO_2 to 87 Mt by 2030. This corresponds to a reduction rate of 12% or 25% for the period from 2005 to 2020 or to

[3] Since these assumptions have been made in the beginning of the project, they did not take into account the impact of the financial and economic crisis starting from autumn 2008.

2030, respectively. In comparison to the WMS, the instruments investigated in the *Structural Change Scenario* cut greenhouse gas emissions in residential buildings by a further 24 or 50 Mt of CO_2 by 2020 or 2030 to 79 or 36 million t, respectively. Compared to 1990, these figures are equivalent to overall emissions reductions of more than 40% by 2020 and of about 72% by 2030.

Reference scenario	Structural change szenario
Quantifiable instruments	
KfW CO_2 Buildings Rehabilitation Programme	Amendment of the 2009 Energy Savings Directive (EnEV)
Housing Modernization Programme	Heat contracting for rented accommodation
Ecological Construction Programme	Right to the reduction of rent and heating costs
KfW Home Ownership Programme	Application of the Renewable Energies Heat Act to old buildings
Urban restructuring scheme for East Germany	Demolition premiums for the replacement of old buildings
Council housing schemes	Energy efficiency as a rent-index-relevant figure
Renewable Energies Market Incentives Programme	Tightening of retrofitting requirements
Amendment of the 2007 Energy Savings Directive (EnEV)	Improved application of the Energy Savings Directive (EnEV)
Renewable Energies Heat Act (EEWärmeG)	Law on renewable energies heat for large-scale equipment
Amendment of the Directive on Heat Cost Allocation (HeizkostenV)	Compulsory connection to district heating networks
On-site energy consultation	Optimization of the KfW programmes
	Tax breaks as incentives for modernization and renewables
Soft and non-quantifiable instruments	
German Energy Agency	Intensification of energy research and innovation
Information and motivation	
Proactive education and quality improvement drives	
R&D in the areas of buildings and heating	

Table 2: Policy instruments and measures analyzed in the two scenarios

	1990	2005	2010	2015	2020	2025	2030
	CO2 eq. (in kt)						
Development 1990 - 2005	131.476	116.157					
With measures scenario			114.459	108.584	102.111	94.972	87.012
Structural change scenario			113.637	99.652	78.501	57.419	36.491
			Changes from 1990 in %				
With measures scenario			-13	-17	-22	-28	-34
Structural change scenario			-14	-24	-40	-56	-72
			Changes from 2005 in %				
With measures scenario			-1	-7	-12	-18	-25
Structural change scenario			-2	-14	-32	-51	-69

Table 3: Comparison of emission savings up to 2030 in the two scenarios for residential buildings

For the building in industry and in the tertiary sector (non-residential buildings), the same scenarios are calculated as for residential buildings. The exploitation of modernization potentials is considered to be 32% in the additional measures programme for 2005, a figure which is increased to 37% by 2020 and to 42% by 2030 and thus equivalent to the residential building sector. The *Structural Change Scenario* assumes that, in particular, a further tightening of the EnEV 2009 provisions from 2013 and an improved application of the directive will increase potential exploitation to 65% by 2020.

In the *With Measures Scenario*, greenhouse gas emissions can be reduced by 54 million t to 43 million t by 2020 and to 32 million t by 2030 starting from 2005 (Table 4). For overall emissions, this corresponds to a reduction rate of about 52% (2020) or 64% (2030), respectively, from a 1990 baseline. These significant reductions result from the replacement of boilers, building envelope modernizations and increasing utilization of solar systems and biomass firing systems. In addition, a considerable proportion of the reductions is due to demolishing buildings and replacing them with new ones.

In comparison to the WMS, the measures assumed for the *Structural Change Scenario* can reduce emissions by a further approx. 12 Mt (19 ‘Mt) to about 31 million t of CO2 (12 Mt) by 2020 (2030). This ambitious scenario could cut emissions by almost 43% by 2020 and by a total of 77% by 2030 from a 2005 baseline.

	1990	2005	2010	2015	2020	2025	2030
	CO2 eq. (in kt)						
Development 1990 - 2005	88.543	54.245					
With measures scenario			50.931	47.155	42.774	37.783	31.975
Structural change scenario			50.273	41.188	31.013	20.976	12.462
			Changes from 1990 in %				
With measures scenario			-42	-47	-52	-57	-64
Structural change scenario			-43	-53	-65	-76	-86
			Changes from 2005 in %				
With measures scenario			-6	-13	-21	-30	-41
Structural change scenario			-7	-24	-43	-61	-77

Table 4: Comparison of emission savings up to 2030 in the two scenarios for non-residential buildings

Residential electric appliances

For the electric uses, a computational model is used to determine the current and future power demand for electric applications which includes the following demand-determining components: the stock of appliances for each product group, the average power input of the products and applications in the different operating modes[4] and the respective patterns of use (Figure 2). The resulting structure of electricity consumption German households (incl. space heating and hot water which was calculated within the building model described above) is shown in Figure 3.

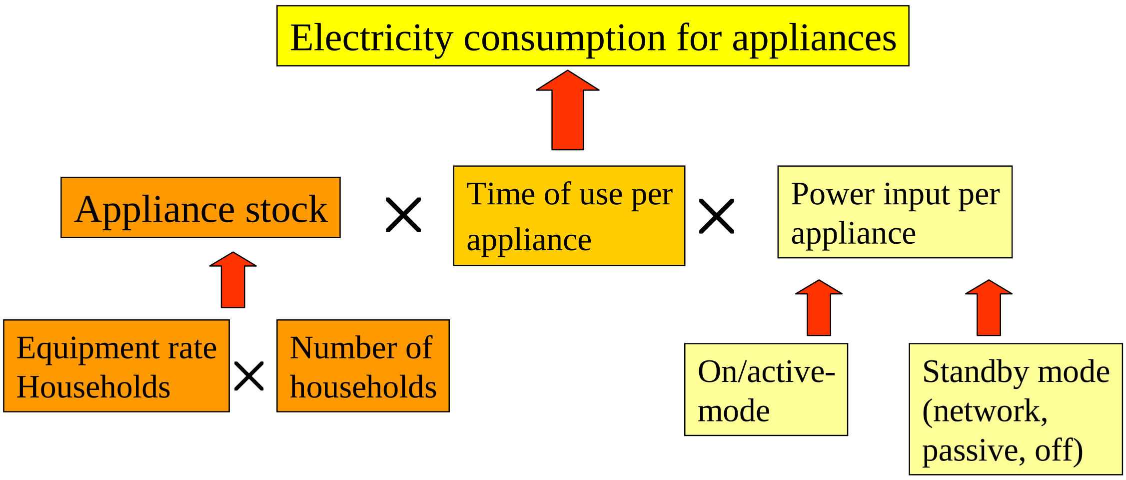

Figure 2. Model to determine energy consumption for electrical appliances in the residential sector

In addition, the impact of policy measures to improve energy efficiency, which were implemented or at least decided in Germany until mid 2008, is included in the *With measures Scenario*. For residential appliances, only the labelling of electric household appliances minimum efficiency standards for cooling appliances, i.e. the implementation of the EU Directive 92/75/EC on energy labelling and Directive 96/57/EC on efficiency requirements for refrigerators and freezers into German law, have been considered. The impact of all planned or possible measures after mid 2008 is included in the *Structural Change Scenario*.

4 On or active mode and standby mode (including: network-standby, passive standby, off-mode, off)

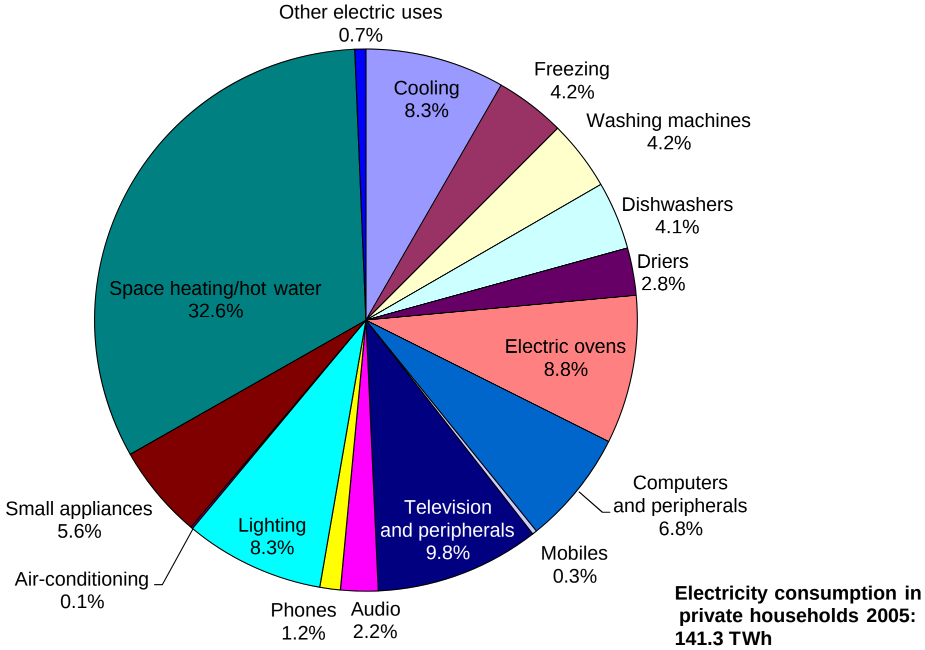

Figure 3. Structure of electricity consumption in German households in 2005

The highest impact is assumed for the setting of ambitious minimum efficiency standards for a considerable number electrical appliances including the big household appliances, consumer electronics and office equipment under the EU Ecodesign Directive (2005/32/EC) in combination with an extension and dynamic arrangement of the appliance labelling by the planned revision of the EU Energy Labelling Directive. For this bundle of measures, which has to be accompanied by an extension of already existing information campaigns, additional energy savings of about 18 TWh are estimated until 2030. Additional energy savings of 5 TWh could be reached until 2030 by the step-by-step introduction of smart meters in private households, giving more current information on electricity consumption. It is assumed that at least 5 % of electricity consumption can be saved per household and that about 75 % of the households will have a smart meter until the mid 2020s. The third possible policy measure which was taken into account in the *SCS* are financial incentives for introducing new, highly-efficient household appliances to the market as they have e.g. been announced in the German Energy Efficiency Action Plan for a limited time period (BMWi 2007), though not yet introduced. The possible savings of this measure are estimated at 2 TWh until 2020.

Based on the model assumptions on the appliance stock and the specific electricity consumption per appliance and taking into account the impact of the policy measures described above, total electricity consumption in private households until 2030 in the *With measures Scenario* is assumed to remain almost constant until 2030 (Table 5). If space heating and hot water is not taken into account, an increase of electricity consumption by almost 10 % is calculated in the WMS. Due to the additional energy saving measures which are assumed in the *Structural Change Scenario*, a significant consumption decrease can be reached both with and without space heating and hot water.

	2005	2010	2020	2030
	Electricity consumption in TWh			
With measures Scenario (WMS)	**141.3**	**146.1**	**146.0**	**138.3**
Large household appliances	45.8	46.1	45.6	44.2
Consumer electronics, office equipment	28.7	34.9	40.0	39.5
of which Standby	*8.7*	*9.0*	*6.2*	*6.0*
Lighting	11.8	11.6	10.9	10.0
Space heating/hot water	*46.0*	*44.3*	*39.8*	*34.4*
Other electric uses	9.0	9.3	9.8	10.1
WMS without space heating/hot water	***95.3***	***101.9***	***106.3***	***103.8***
Structural Change Scenario (SCS)	**141.3**	**141.7**	**115.3**	**86.6**
Large household appliances	45.8	45.6	40.1	36.6
Consumer electronics, office equipment	28.7	33.1	31.6	26.7
of which Standby	*8.7*	*8.1*	*4.8*	*4.2*
Lighting	11.8	11.4	8.6	6.3
Space heating/hot water	*46.0*	*42.5*	*25.8*	*8.2*
Other electric uses	9.0	9.1	9.1	8.8
SCS without space heating/hot water	***95.3***	***99.2***	***89.5***	***78.4***

Table 5: Development of electricity consumption in private households in the two scenarios until 2030

Electricity uses in the tertiary sector

Electricity demand in the tertiary sector accounts for about 133 TWh in Germany in 2007 (more or less constant since 2000) and thus is a very relevant field for energy efficiency policies. The fuel demand in the tertiary sector is mainly due to space heating and sanitary hot water in non-residential buildings, which has already been discussed above.

Both calculated scenarios consider a row of policies that are addressed towards reducing electricity demand in the tertiary sector. The *WMS* covers an energy efficiency information program, labeling of office equipment (Energy Star) and support for public procurement for energy efficient appliances. The *SCS* additionally covers the minimum energy performance standards (MEPS) from the Ecodesign directive (2005/32/EC; revised: 2009/125/EC), an extension of the current labeling scheme for household appliances to a considerable number of other energy-related products under the revised EU Labelling Directive, support for common procurement of energy efficient appliances, white certificates, extension of the scope of the information programs, energy efficiency contracting and the implementation of a national energy efficiency fund.

An end-use accounting model was used for the scenario calculations. The model distinguishes ten electricity end-uses that were estimated to be responsible for the highest share in the sector's electricity demand (see Figure 4). Improvements in energy efficiency of these end-uses are modeled through the diffusion of energy saving options through the technology stock. The diffusion rates are exogenously defined and energy prices are not explicitly taken into account. Some of the saving options are clearly defined as technical improvement measures or alternative more efficient appliances others represent bundles of improvement measures also covering changes in behavior. Consequently, policies are modeled by considering them in the exogenous scenario assumptions on the diffusion of saving options. The advantage of this approach is a very clear allocation of policies to certain end-uses, while the disadvantage is the lacking energy price elasticity. Main driver for the evolution of the end-uses is the development of floor area in the tertiary sector buildings, which is assumed to be rather constant within the scenario timeframe.

It should be noted that the available (official) data about energy demand in the tertiary sector (consumption of different appliances or subsectors) is very rare. The German energy balances (AGEB 2009) only provide final energy demand of the tertiary sector as a whole, differentiated by energy carrier. Thus, further studies had to be used as data basis. Among these is an evaluation of energy demand in the tertiary sector in Germany (Schlomann et al. 2009), several preparatory studies for the Ecodesign Directive (Fraunhofer IZM) 2008; Monier et al. 2007; Radgen et al. 2007; TCO et al. 2007;

Tichelen Van et al. 2007a; Tichelen Van et al. 2007b) and further studies on the tertiary sector (Adnot et al. 2003; Bertoldi et al. 2007; Schäppi et al. 2007). Particularly the preparatory studies for the Ecodesign Directive were used as basis for the shares in Figure 4 as well as to estimate the future saving potentials.

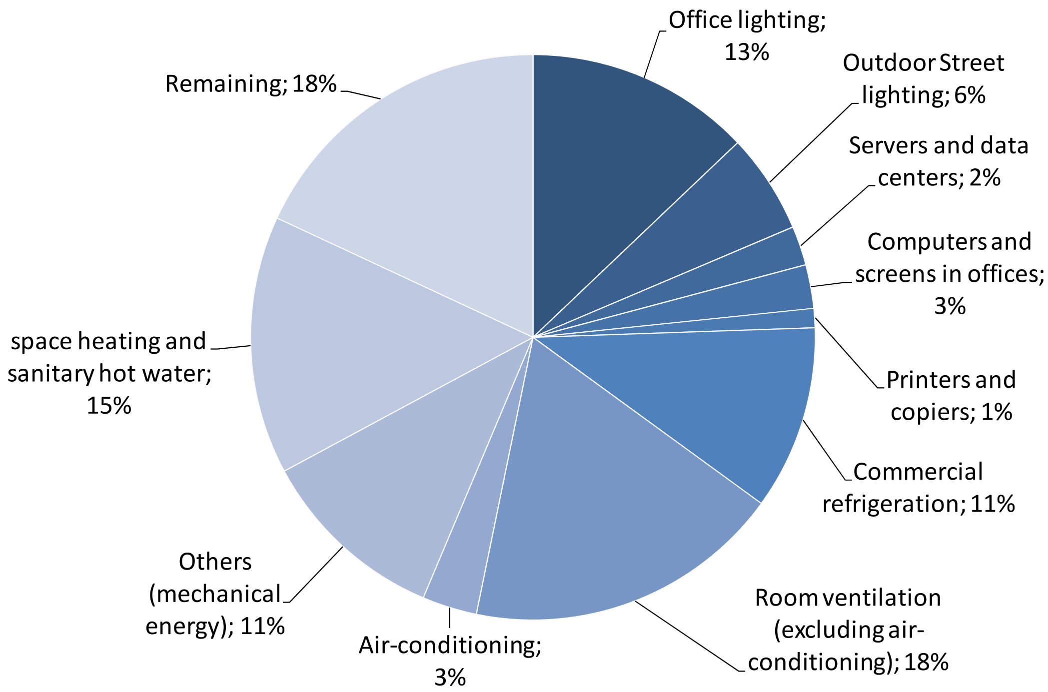

Figure 4: Tertiary sector electricity demand by end-use in 2005

The results show a falling electricity demand until 2030 for both scenarios. Because of the assumption of more or less constant floor space until 2030 as main driver for the end-uses, even the low energy efficiency improvements in the *WMS* suffice to result in a falling electricity demand. In contrast, the *SCS* scenario assumes further strong energy efficiency policies that result in an additional reduction of electricity demand of 26% in comparison to the *WMS*. Single most important policy is the national implementation of the EU Ecodesign Directive in connection with the assumption on demanding MEPS for a considerable number of energy-related products. These are responsible for 35% of the additional reduction in the SCS scenario. Other measures with huge impact are the introduction of an energy efficiency fund in Germany (14%) and energy efficiency contracting (10%).

Tertiary		1990	1995	2000	2005	2010	2015	2020	2025	2030
		Energy demand PJ / TWh								
WMS	Fuels [PJ]	466	220	142	173	176	173	170	165	160
	Electricity [TWh]	116	124	140	131	132	127	123	120	116
SCS	Fuels [PJ]	466	220	142	173	174	168	160	155	143
	Electricity [TWh]	116	124	140	131	130	117	106	94	86
Comment: without fuels for electricity autoproduction in industry; without fuels for space heating and hot water										

Table 6: Resulting energy demand in the tertiary sector for both scenarios

Electricity and fuel demand in industry

With 2645 PJ, the industrial sector accounts for about 30% of total final energy consumption in Germany, showing an increase of about 10% since 2000. Electricity demand increased 12% in the same period to a total of 841 PJ in 2007. On the sectoral level, the highest demand increases were recorded in the pulp and paper industry (+36% from 2000 to 2007) and the basic chemicals industry (+25%). Also the less energy intensive subsectors showed considerable growth, while the other chemicals (-15%) the glass and ceramics industry (-6%) and the iron and steel industry (-5%) showed demand reductions.

Thus, the sub-sectors showed a different and varying development as compared to the industry as a whole.

For the scenario calculations we assumed a variety of different policies. In the *WMS* the EU emissions trading scheme is the most important single policy, directed towards the very energy intensive industries. Another important policy is the Special Fund for Energy Efficiency in SME from the KfW providing subsidies for energy efficiency audits and low interest credits for investments in energy efficiency. In the *SCS*, a row of additional policies were considered, to a large extend addressing saving potentials in cross-cutting technologies. Among these are MEPS and labeling in the frame of the EU Ecodesign Directive, a white certificate system, energy management systems like the energy efficiency networks of which 30 were recently implemented in Germany, energy efficiency contracting and the introduction of an energy efficiency fund in Germany.

The model used for the calculations, ISIndustry, was recently used for analyses of energy efficiency opportunities in the industrial sector in Europe (Fraunhofer ISI et al. 2009) as well as in Germany. Like the tertiary model, ISIndustry is a typical bottom-up model, but shows a lot more details - also due to the better data availability. Main driver for the projections is the development of value added on a subsector level and the physical production of more than 30 energy intensive products. ISIndustry explicitly considers so called energy saving options – technical or behavioral measures that improve energy efficiency of certain processes or technologies. By further diffusion through the technology stock, the energy saving options reduce energy demand. Besides the technical saving potential, investment and running cost are allocated to each saving option, allowing for an analysis of cost-effectiveness depending on the energy carrier and CO_2 emission certificate prices. Due to the high share of motor systems in total electricity demand, in particular in the less energy intensive sectors, the model distinguishes between cross-cutting technologies (motors, lighting) and process specific technologies (e.g. blast furnace in steel making).

As in the tertiary model, also the industrial model allows allocating policies directly to certain technologies, but the model additionally allows an assessment of the cost-effectiveness of certain saving options in the light of chosen policies. E.g. for the emissions trading scheme an estimation of the additional saving options that become cost-effective when a certificate price of e.g. 30 Euros per ton is applied is possible. For other policies, like the special fund for SME it was (exogenously) assumed that they have direct effect on the diffusion rate of certain saving options. The technology specific modeling approach is even more suitable to consider the impact of the MEPS under the EU Ecodesign Directive. These can directly be translated into minimum efficiency levels of new appliances from a certain year onwards. To conclude, the technology specific modeling approach has clear advantages for the modeling of policies that aim at certain technologies or certain industrial sectors only. However, the modeling of price based instruments is still a challenge. Even if investment costs are considered, the actual behavior of firms is difficult to estimate, because they often do not act according to simple cost-minimization rules.

As mentioned, the official energy statistics are a lot more detailed for the industrial sector, compared to the tertiary sector. The Germany energy balance (AGEB 2009) differentiates between 14 industrial branches, allowing a detailed consideration of structural shifts. However, the enormous heterogeneity and variety of industrial production processes and technologies also poses limits to how detailed technologies can be represented in the model. In particular the cost data and the current specific energy consumption of industrial plants are difficult to come by and often have to be estimated, based on case studies and expert interviews. For the cross-cutting technologies, an analysis of the saving potential in Germany was used as major data basis (Schmid et al. 2003) and also several Europe-wide studies provided further input for the technology data (Almeida et al. 2008; ETSU et al. 2001; IEA 2006; Mecrow, Jack 2008; Radgen 2002; Radgen et al. 2007; Radgen/Blaustein 2001).

The calculation results for the *WMS* show a constant demand increase for electricity and fuels, which both show a growth of about 13% from 2005 to 2030 (see Table 7). This growth is strongly driven by the increase in value added of the less energy intensive sub-sectors and also partly by the physical production of certain energy intensive sub-sectors. The physical production of energy intensive products like steel, cement and chlorine is assumed to remain on a rather constant level, while the production of paper increases by about 50% and the primary aluminum production is completely phased out by 2030. Value added for the industry as a whole is assumed to increase by about 50% in comparison to 2005. In particular the less energy intensive sub-sectors, like machinery (+96%), metal processing (+80%), vehicle construction (+59%) but also chemicals (+40%) and non-ferrous metals (+52%) show high growth rates that have a strong impact on energy demand.

For the *SCS* the same assumptions on value added and production development were taken, but the technical change towards improved energy efficiency is considerably stronger. Electricity demand fell by 7%, mostly due to the many programs directed towards electric motor systems. The situation seems different for fuels demand, which is supposed to grow even stronger than in the WMS with a total increase of 27% (a little less strong increase can be observed in the emission projections due to fuel switch). This increase does not really reflect an increase in fuel demand, but is rather due to a shift from industrial CHP to separated heat and steam production and the related accounting peculiarities. Due to the high share of renewable energy in electricity generation in 2030, the market share of industrial CHP is pushed back. Thus, the shift from industrial CHP towards separated steam and heat generation also implies a shift of fuel demand from the electricity module to the industry module, resulting in the fuel demand increase in the industry balances and a respective reduction in the electricity production sector balances (see Table 7).

With regard to policies, the analysis also showed that many of the policies were directed towards cross-cutting technologies (mainly electricity-based) and less energy intensive SME, while the energy intensive processes (with a high share of fuels) were mainly addressed by the emissions trading scheme.

Industry		1990	1995	2000	2005	2010	2015	2020	2025	2030
		Energy Demand PJ / TWh								
WMS	Fuels [PJ]	1,730	1,607	1,567	1,504	1,532	1,580	1,612	1,667	1,700
	Electricity [TWh]	208	190	208	234	240	245	249	258	265
SCS	Fuels [PJ]	1,730	1,607	1,567	1,504	1,548	1,633	1,730	1,811	1,915
	Electricity [TWh]	208	190	208	234	228	221	213	215	217
Comment: without fuels for electricity autoproduction in industry; without fuels for space heating and hot water										

Table 7: Resulting energy demand in the industry sector for both scenarios

Total development of energy requirement and emissions

The total final energy consumption including the transport sector (which has not been analyzed in detail before) in the *With Measures Scenario* decreases by around 4 % from 2005 to 2030. The final energy requirement for national transport decreases again after a slight increase before 2015, and in 2030 lies at approximately 2 % below the level of 2005. A significant expansion of the energy requirement is calculated for international air traffic: from 2005 to 2030, the fuel and energy requirement increases in this area by around 81 %. In the *Structural Change Scenario*, the forecast period of 2005 to 2030 is characterized by a significant reduction in final energy requirement. Overall, this requirement decreases by around 24 %. The reduction in final energy requirement is also the key determining factor for the decreasing emissions in the end consumption sectors, since although the structure of the final energy output changes as compared to the WMS. Here, the trends of the WMS are intensified: reduction in the share of mineral oil products to around 28 % by 2030, growth in the natural gas share to approximately 27 %, increase in the direct share of renewable energy sources to almost 17 %. The strongest reduction in consumption results in this scenario for the tertiary sector (incl. non-residential buildings). In 2030, the final energy requirement here is approximately 51 % below the level of 2005. Significant energy savings are also made in the transport sector. Here, energy savings of around 24 % for national transport and 25% for international air traffic are achieved. A significant (percentage) contribution to a reduction in levels is anticipated for private households. During the forecast period, the final energy requirement is reduced in this sector by 46%. For industry, a growth in energy requirement of about 10% also remains in this scenario.

The primary energy requirement results from the final energy requirement, the use of fuel for electricity generation and the consumption in the other conversion areas and non-energy consumption of energy resources. In the *With Measures Scenario*, the primary energy requirement is reduced from 2005 to 2030 by 0.6 %. With regard to the structure of the primary energy output, two different trends emerge, however. The use of nuclear energy, brown coal and hard coal, mineral oil and natural gas declines, while renewable energies output increases. In the *Structural Change Scenario,* the period from 2005 to 2030 is initially characterized by a significant decrease of primary energy by approximately 23 %. In addition to this reduction in the overall primary energy requirement, the structure of the primary energy output is dominated by three different trends: a comparatively slight decrease in natural gas consumption to a level of around 11 % below that of 2005, a huge decrease in the use of mineral oil, coal and nuclear-generated energy and a far greater increase in the contribution made by renewable energy sources to primary energy. The renewable energy sources will be the most important energy source group in 2030, with an output share of 35 %.

The development of the total level of greenhouse gas emissions results on the one hand from the energy-related greenhouse gas emissions and on the other from the greenhouse gas emissions from industrial processes, product use, agriculture and waste management. An overview of the development in all sectors is given in Table 8. The energy-related greenhouse gas emissions are determined to a large extent by the CO_2 emissions from the combustion of fossil energy sources in the energy sectors, the final consumption sectors of industry, households, transport, tertiary and the transient CH_4 emissions from coal mining and from the oil and gas industry. In the *With Measures Scenario*, the greenhouse gas emissions from combustion decrease from 2005 to 2030 by 136 million tonnes CO_2 eq. Around one-third (33%) of this reduction in emissions is achieved in the final consumption sectors, although significant reductions in the household, tertiary and transport sectors are offset by a slight increase in emissions in the industrial sector. The overall contribution of the energy sectors (without industrial power stations) to the reduction in emissions with regard to greenhouse gas emissions from combustion is approx. 40 % for the given period. The CH_4 emissions from coal mining and the oil and gas industry decrease by around 55 % between 2005 and 2030 in the With Measures Scenario. This development results above all from the termination of hard coal mining in Germany. The development of the energy-related greenhouse gas emissions in the *Structural Change Scenario* is in turn dominated by the progression of CO_2 emissions from combustion processes. Overall, a reduction of 441 Mt CO_2 eq. in greenhouse gas emissions from combustion results for this period, corresponding to a reduction of 55 %. The share of final consumption sectors (above all in the area of buildings and transport) in the overall reduction in emissions amounts to approximately 43%. For the energy-related greenhouse gas emissions overall, a reduction of 450 Mt CO_2 eq., or 55 %, results in the Structural Change Scenario.

In Germany, the development of greenhouse gas emissions from industrial processes is dominated above all by the development of the CO_2 emissions from steel and cement production and the N_2O emissions from the chemical industry. While in the *With Measures Scenario* only a stabilization of the emissions at the 2005 levels can be achieved, the additional measures in the *Structural Change Scenario* result in a reduction in these emissions of about 26 %. For greenhouse gas emissions from agriculture, a reduction in emissions of around 8 million tonnes CO_2 eq. results above all due to the structural development of the sector (animal stocks, etc.) from 2005 to 2020. This corresponds to a reduction of approx. 13 % which were not varied further between the scenarios. A significant contribution to the development of the greenhouse gas emissions is made by developments in waste management, however. The development of CH_4 and N_2O emissions from this source area is – with a time delay of several years – determined primarily by the waste management measures taken, which from 2005 led to a far-reaching ban on the disposal of organic substances. Accordingly the greenhouse gas emissions from waste management decrease by around 9 Mt CO_2 eq. or around 63 % in both scenarios.

However, it should be noted that the emission trends described do not include developments in international air traffic (and to a lesser extent, marine shipping). In particular, the highly dynamic development in international air traffic results in a growth in greenhouse gas emissions for international transport in the With Measures Scenario of 17 Mt CO_2 eq. from 2005 to 2030, corresponding to a growth of 47 %. At the same time, the scenario analysis also shows that when appropriate measures are taken, the emissions from international air traffic can be significantly reduced in the Structural Change Scenario, so that a reduction of 5 million tonnes CO_2 eq. (i.e. around 18 %) results here for international traffic.

For the overall greenhouse gas emissions (without land use, changes to land use and forestry), in the *With Measures Scenario*, a reduction of 178 Mt CO_2 eq., or 17.8 %, results for the period 2005 to 2030. Compared to the basic levels specified in the Kyoto Protocol, this corresponds to a reduction of around 30 % by 2020, with a reduction in emissions of 33 % by 2030. For the *Structural Change Scenario*, the reduction in emissions totals around 49 % from 2005 to 2030. Compared to the base years in the Kyoto Protocol, this emission path corresponds to a reduction in emissions of 43 % by 2020 and 58 % by 2030.

	2000	2005	2010	2015	2020	2025	2030
	Million t CO_2 eq.						
With Measures Scenario							
Energy sectors	351,3	366,1	344,5	352,7	299,6	315,8	307,2
Industry	**99,2**	**104,6**	**99,5**	**100,2**	**101,3**	**105,1**	**107,7**
Tertiary	**54,6**	**54,2**	**50,9**	**47,2**	**42,8**	**37,8**	**32,0**
Residential	**118,9**	**116,2**	**114,5**	**108,6**	**102,1**	**95,0**	**87,0**
Transport	184,3	165,5	166,3	167,0	157,7	148,9	136,6
Transient emissions from energy sectors	19,8	12,7	11,5	9,3	6,7	6,3	5,8
Industrial processes	101	106	100	90	89	89	88
Product use	1	1	1	1	1	1	1
Agriculture	67	64	60	59	58	56	55
Waste management	22	14	10	8	7	6	5
Total	1.019,5	1.004,0	957,9	943,1	864,2	860,8	825,7
compared to 2005	*1,5%*	-	*-4,6%*	*-6,1%*	*-13,9%*	*-14,3%*	*-17,8%*
compared to 1990	*-17,0%*	*-18,2%*	*-22,0%*	*-23,2%*	*-29,6%*	*-29,9%*	*-32,7%*
compared to base year [a]	*-17,3%*	*-18,5%*	*-22,3%*	*-23,5%*	*-29,9%*	*-30,2%*	*-33,0%*
Recalculation:	-	-	-	-	-	-	-
Internat. civic air traffic and marine shipping	*24,8*	*29,3*	*32,8*	*36,3*	*39,6*	*42,9*	*46,0*
Structural Change Scenario							
Energy sectors	351,3	366,1	328,3	292,2	204,8	168,6	116,7
Industry	**99,2**	**104,6**	**96,6**	**98,9**	**101,3**	**104,8**	**97,6**
Tertiary	**54,6**	**54,2**	**50,3**	**41,2**	**31,0**	**21,0**	**12,5**
Households	**118,9**	**116,2**	**113,6**	**99,7**	**78,5**	**57,4**	**36,5**
Transport	184,3	165,5	156,2	146,4	128,5	115,3	102,4
Transient emissions from energy sectors	19,8	12,7	11,4	8,9	5,6	4,5	3,4
Industrial processes	101	106	98	87	84	83	82
Product use	1	1	1	1	1	1	1
Agriculture	67	64	60	59	58	56	55
Waste management	22	14	10	8	7	6	5
Total	1.019,5	1.004,0	925,5	841,9	698,7	618,1	512,8
compared to 2005	*1,5%*	-	*-7,8%*	*-16,1%*	*-30,4%*	*-38,4%*	*-48,9%*
compared to 1990	*-17,0%*	*-18,2%*	*-24,6%*	*-31,4%*	*-43,1%*	*-49,7%*	*-58,2%*
compared to base year [a]	*-17,3%*	*-18,5%*	*-24,9%*	*-31,7%*	*-43,3%*	*-49,8%*	*-58,4%*
Recalculation:							
Internat. civic air traffic and marine shipping	*24,8*	*29,3*	*31,2*	*20,2*	*21,5*	*22,8*	*24,0*

Note: [a] The base year is 1990 for carbon dioxide, methane and nitrous oxide, and 1995 for HFCs, PFCs and sulphur hexafluoride; as base emission, the value specified in FCCC/KP/CMP/2008/9/Rev.1 has been used

Table 8: Development of greenhouse gas emissions according to sector, 2000-2030

The most influential climate and energy policy measures

The developments in emissions levels are based on different climate and energy policy measures or targets. The greatest contributions to emission reduction by 2030 in the *With Measures Scenario* (without taking overlaps and indirect effects into account) are made by:

- The extension of electricity generation from renewable energy sources, at more than 36 million CO_2,
- The revision of the EU emission trading scheme, at more than 15 million tonnes CO_2,
- The incorporation of industrial N_2O emissions into the EU emission trading scheme, at 40 million tonnes CO_2 eq.
- The introduction of mandatory admixing for fuels, at 11 million tonnes CO_2
- The KfW CO_2 building refurbishment programme, at 12 million tonnes CO_2
- The introduction of the Technical Instruction on Waste from Human Settlements and the Ordinance on Landfills, at 9 million tonnes CO_2 eq.
- Electricity savings resulting from various measures, at more than 7 million tonnes CO_2
- The Energy Savings Act, at 7 million tonnes CO_2
- A reduction in car fleet consumption as part of the European CO_2 strategy for cars, at 6 million tonnes CO_2
- The market incentive programmes for biomass and solar power, at 5 million tonnes CO_2

For the *Structural Change Scenario*, the greatest additional contributions to reduction by 2030 result from the following measures:

- Increased attempts to save electricity, totalling 103 million tonnes CO_2
- The further extension of electricity generation from renewable energy sources, at 75 million tonnes CO_2
- Taxation on aircraft fuels for international air traffic, at 24 million tonnes CO_2 eq.
- The change in power station operation, at 21 million tonnes CO_2
- The extension of the toll on heavy goods vehicles on all trunk roads and on smaller vehicle classes from 3.5 tonnes permissible maximum weight, at up to 11 million tonnes CO_2
- An increase in the implementation of the Energy Savings Act, at 9 million tonnes CO_2
- The continuation and intensification of the emission specifications as part of the European CO_2 strategy for cars, at 9 million tonnes CO_2
- The extension of mandatory retrofitting of buildings, at 7 million tonnes CO_2
- VAT relief on energy refurbishment measures on buildings, at 6 million tonnes CO_2
- The promotion of heat contracting, at 6 million tonnes CO_2
- The introduction of the Renewable Energies Heat Act for larger solar and biomass plants, at 6 million tonnes CO_2

Conclusions and Outlook

In order to develop scenarios for energy requirements and greenhouse gas emissions in Germany until 2030, different sector-specific model analyses were used which were compiled into a consistent and complete quantity structure. This approach, using specific bottom-up models for each sector instead of one macroeconomic top-down model seems to be more appropiate to integrate the impact evaluation of sector-specific energy and climate policy measures into the scenario approach. For integration purposes and to determine total greenhouse gas emissions, a system integration module and an emission calculation model are used with the aid of which the detailed sector results are compressed into a quantity structure which is fully compatible with the German greenhouse gas.

For the overall greenhouse gas emissions (without land use, changes to land use and forestry), in the reference scenario (*With Measures Scenario)*, a reduction of 178 Mt CO_2 eq., or 17.8 %, results for the period 2005 to 2030. Compared to the basic levels specified in the Kyoto Protocol, this corresponds to a reduction of around 30 % by 2020, with a reduction in emissions of 33 % by 2030. For an ambitious *Structural Change Scenario*, the reduction in emissions totals around 49 % from 2005 to 2030. Compared to the base years in the Kyoto Protocol, this emission path corresponds to a reduction in emissions of 43 % by 2020 and 58 % by 2030.

The sector analyses have shown very clearly that clear prospects for the necessary investments in these fields, with clear statements regarding the future incentive signals and frameworks, play a crucial role. This includes long-term support programmes for the building sector, stable framework conditions for renewable energy sources, stable promotion of measures for saving electricity, regulatory framework for the electricity industry, clear innovation signals for the transport sector, the development of energy and transport infrastructures with adequate preparation.

The policy scenario approach in Germany will go on with the Policy Scenarios VI which have already started in the end of 2009. Results will be available in the first half of 2011.

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