Project no.:
019672

Project acronym:
DYNAMIS

Project title:
Towards Hydrogen and Electricity Production with Carbon Dioxide Capture and Storage

Instrument : Integrated project
Thematic priority : 6.1.3.2.4
Capture and sequestration of CO_2, associated with cleaner fossil fuels

Start date of project: 2006-03-01
Duration: 3 years

D 6.1.1
Modelling Framework and Reference Data Report

Revision: Final

Due date of deliverable: 2006-11-30
Actual submission date: 2006-12-06

Organisation name of lead contractor for this deliverable:
Fraunhofer Institute for Systems and Innovation Research

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential , only for members of the consortium (including the Commission Services)	

Deliverable number:	D 6.1.1
Deliverable name:	Modelling Framework and Reference Data Report
Work package:	WP 6.1 Strategic Issues of HYPOGEN
Lead contractor:	Fraunhofer ISI

Status of deliverable		
Action	**By**	**Date**
Submitted (Author(s))	Susanne Schmidt, Clemens Cremer, Fraunhofer ISI	2006-12-06
Verified (WP-leader)	Clemens Cremer, Fraunhofer ISI	2007-01-04
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Abstract
This report describes relevant socio-economic framework data for the model-based of the market position of a HYPOGEN plant. Projections for primary energy prices, for electricity demand of EU Member States and of the greenhouse gas emissions policies are compared. Sets of reference data for the use in the project are suggested.

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1 INTRODUCTION

In work package 6.1 of the DYNAMIS project, the societal anchorage of a HYPOGEN demonstration shall be examined by means of strategic market issues. Four relevant markets have been identified that mainly control the economic feasibility of a power conversion plant producing hydrogen and electricity from decarbonised fossil fuels: the electricity market, the hydrogen market, the emissions trade market for greenhouse gas emissions and the worldwide technology markets.

As a first approach to this analysis, the performance of a HYPOGEN facility within the European electricity markets shall be analysed by integrating this technology option into energy models. Since modelling results and consequently technology and market assessment strongly depend on the framework data, this report is meant to give information about the considered sources for fossil fuel price prognoses, electricity demand forecasts and future emission reduction policies.

All those projections are not developed by the DYNAMIS project team itself but basing on data published in relevant literature. These are, in particular, renowned institutions like the International Energy Agency, the European Union and the Energy Information Administration. Further, national energy studies are considered for projections. Beyond, the scientific literature describes approaches in which future energy supply is assessed from a resource economics' aspect by the integration of macro-economic models. One example is the integrated assessment model for the analysis of sustainable development of energy supply in Germany, which was developed at the University of Stuttgart [Fahl et al., 2004].

<u>Report structure</u>

In Chapter 2, the available sources for primary energy price projections are introduced, whereat international as well as national institutions are considered. Afterwards, actual developments and trends are highlighted, followed by the comparison of the considered price projections for fossil primary energy carriers. Afterwards, a forecast for nuclear fuel is added. Finally, conclusions are drawn which fuel price projection can be regarded as adequate for the HYPOGEN modelling.

Chapter 3 deals with the European electricity demand by depicting the recent development and the values published in the chosen sources. Again, conclusions are made concerning an appropriate projection for the modelling work.

Finally, Chapter 4 gives an overview on the recent discussion on climate change and selective national emission reduction policies, which act as indicators for the chosen projection on greenhouse gas emission policies.

2 PRIMARY ENERGY PRICE PROJECTIONS

For the analysis of a HYPOGEN plant, the most influencing primary energy prices are fossil fuel prices. For this reason, the data sources were collected and charted focusing on price projections for coal, natural gas and oil products. Generally, three European sources have published fuel price projections to 2030, which are listed in Table 2-1. It additionally contains the individual years for which forecasts are made and the date of publication.
Further, research has been made on price projections from national institutions in France, Germany, the United Kingdom and the United States of America. While from France as well as from the UK no tangible figure can be accessed – both of them refer to the IEA World Energy Outlook for future projections - comprehensive data for the U.S. American market can be found at the Energy Information Administration (EIA), which publishes official energy statistics from the U.S. government and develops projections for the national U.S. and the international energy markets by order of the U.S. government. For Germany, the Institute of Energy Economics at the University of Cologne (EWI) together with the Prognos AG published an energy report concerning the development of energy markets until 2030 by order of the Federal Ministry of Economics and Technology (BMWi), which also provides fuel price prognoses. The EIA as well as the EWI/prognos source complete Table 2-1.

Table 2-1: Overview of sources of data for primary energy price projections

Organisation	Title of source	Years provided	Date of publication
International Energy Agency	World Energy Outlook 2006 [IEA, 2006]	2000, 2005, 2010, 2020, 2030	November 2006
European Union	PRIMES Study [Capros et al., 1999]	2000, 2005, 2010, 2020, 2030	1999, updated May 2006
European Union	WETO-H2 project [WETO-H2, 2006]	annual values from 2001 to 2050	January 2006
Energy Information Administration	Official energy statistics from the U.S. government [EIA, 2006a]	annual values from 2003 to 2030	February 2006
EWI / prognos	The Development of the Energy Markets until the Year 2030 [EWI/prognos, 2005]	2000, 2010, 2015, 2020, 2025, 2030	April 2005

In the following chapters, the recent developments on the international fossil fuel markets are illustrated as well as their mainstream trends in the near future. Finally, the values provided by the data sources mentioned above are compared and conclusions for their model use are drawn.

2.1 Actual Developments and Trends on the fossil fuel markets

2.1.1 Development from 2000 to 2004

The energy price statistics provided by the International Energy Administration [IEA, 2005] for the years 2000 until 2004 show some short-term trends that occurred on the international markets for primary energy carriers. These trends however reflect quite well the general expectations for the energy price development. The crude oil price started to rise remarkably. This fact will be examined more closely in the following paragraph. The price for natural gas followed this development to certain extend, indicating the rising demand for gas on the world market. Even the price for hard coal, which is significantly lower than the one for oil and gas, underwent an increase in price, which can be imputed to the economical boom in the Asian countries and the connected growth in energy demand, especially for coal in China.

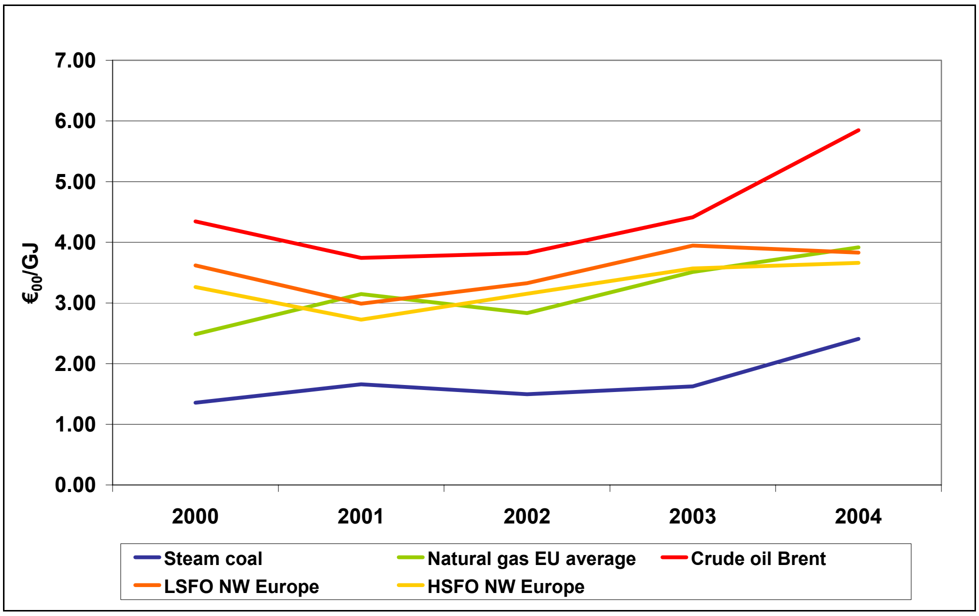

Figure 2-1: Development of prices for fossil energy carriers in Europe 2000-2004

2.1.2 Trends on the international oil and gas markets

In recent years, the international crude oil price reached an exceptionally high level, with the latest peak of 78.29 $/barrel Brent in August 2006. The main reason for this development is assumed the political tensions in the Middle East. Another factor might have been extensive "hedging" and speculations on the commodity markets [Beuret, 2006]. Meanwhile, the crude oil price has fallen to a level of about 60 $/barrel in November 2006.
In the near future, crude oil prices are expected to swing into a level of maximum 50 $/barrel by 2010 [Beuret, 2006]. For the subsequent years, most sources of data assume a moderate annual increase in fuel oil prices until 2030.

Approaches that foresee the "Peak Oil" to occur within the next decades do not play any role in all of the considered literature. "Peak Oil" or "Hubbert's Peak" refers to that point of time when global oil production reaches its maximum, which is supposed to take place when half of the reserves are exploited. Assuming that the oil production follows a bell-shaped curve, there will be a gap between oil supply and demand afterwards, so that prices will increase rapidly [Hubbert, 1956]. Although there is a controversial discussion about Hubbert's theory and the probable date of the oil production peak, none of the considered sources imply its price effects in the forecasts[1]. Instead, other global conditions and development are expected to make a decisive impact on the oil price. The following factors might influence the oil price in the long-term and thus have to be incorporated in the price projections:

- the development of the worldwide energy demand, predominantly driven by the emerging economies of China and India [EWI/prognos, 2005]
- the deteriorating exploitability of existing oil deposits [EWI/prognos, 2005]
- the exploitation of new conventional and unconventional oil and gas deposits[2] [Beuret, 2006]
- the availability and competitiveness of substitute energies [Beuret, 2006]
- emission reduction policies [DTI, 2003]

Altogether, the oil price is expected not to be subject to dramatic changes in development for longer periods. Nevertheless, it is also unlikely to perform in such a well-balanced way that theoretical projections foresee. The following events might cause remarkable fluctuations in the oil price curve in the short- and medium term:

- geopolitical disruption or damage to infrastructure [DTI, 2003]
- changes in the OPEC hauling capacities [Beuret, 2006]
- changes in the worldwide refinery capacities, which are assumed to be rather low [Beuret, 2006]
- extensive speculations, forward contracts and hedging activities on the commodity markets [Beuret, 2006]

The price projections for natural gas are geared closely to the forecasted oil price development, since similar influencing factors as for the oil price can be assumed. IEA and PRIMES impute exactly the same growth rates beyond 2010, while WETO-H2 and EWI/prognos expect the oil prices to rise slightly more than the gas prices. Finally EIA presumes the gas price to grow to a higher extend than the oil price between 2015 and 2030 (cf. Figure 2-2).

[1] an approach for the integration of Hubbert's Peak into prognoses can be found in [Fahl et al., 2004]
[2] such as extra-heavy oil (oil sands), and bitumen, syncrude, shale oil and conventional heavy oil and coalbed methane, tight gas, gas shale and landfill/biogas, respectively [Rajan, 2004]

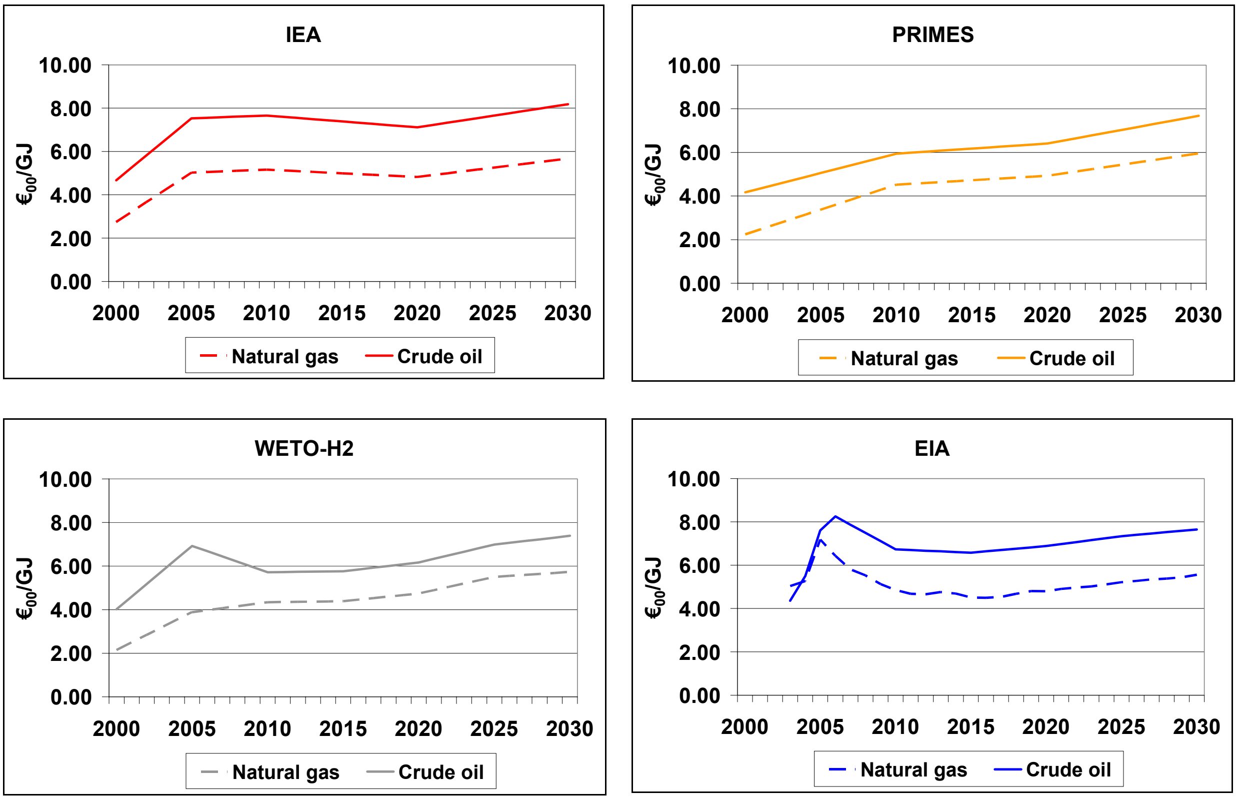

Figure 2-2: Dependency of gas price projections on crude oil price forecasts

2.1.3 Trends on the international coal market

The situation on the world coal market is assumed to stay stable until 2030 since future deterioration in exploitation will be more or less equalized by technological progress [EWI/prognos, 2005]. Furthermore, hard coal resources will not run out for centuries [BMWi, 006], so that shortage effects can be excluded in a global context. The most influencing factor for rises in the international coal price will be the global CO_2 emission mitigation targets; however, those can be balanced in approximately equal measure by new technologies for carbon capture and storage [EWI/prognos, 2005]. Overall, the sources of data anticipate a moderate increase in the coal price.

2.2 Comparison of fossil fuel price projections

In this chapter, the projections of the five sources of data are illustrated by contrasting them for each primary energy carrier. All of them refer to a reference scenario, which is meant to continue the current trends and policies without significant changes in the future. Several variant scenarios have been developed by [EC, 2004a], presuming amongst others higher oil and gas price scenarios, divergent nuclear power scenarios or cases with different greenhouse gas emission policies.

2.2.1 Prognoses on oil prices

The range of oil products traded on the international energy markets is wide and manifold. Accordingly, there cannot be found one singular product in all the statistics. Except for EWI/prognos, all sources provide at least forecasts on crude oil price, which can be seen in Figure 2-4.

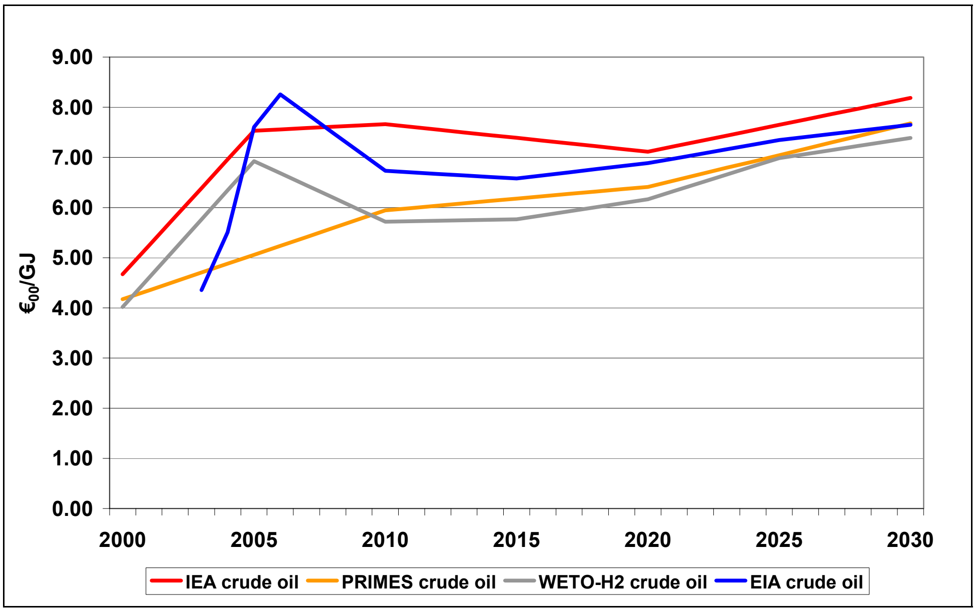

Figure 2-3: Comparison of crude oil price projections from 2000 to 2030

Amongst the illustrated forecasts, the EIA provides the data, which reflects the actual situation of the crude oil price development most appropriately, but is still one third lower than the observed 2006 peak. Whereas the EIA and WETO-H2 expect the crude oil price to fall significantly from 2006 until 2010, the IEA price projection shows a slight increase during this time segment. Afterwards, the prices are supposed to grow moderately until 2030 in all three sources. The PRIMES figure, which depicts values that were generated at the end of the last century, contains a steady growth in crude oil prices from 2000 until 2030. With respect to the PRIMES projections, it should be noted though that they have been made starting at a considerably lower level of oil prices.

Two of the considered sources provide data for other oil products. Figure 2-3 shows the projections for residual fuel oil and distillate fuel oil as provided by EIA and for heavy fuel oil and light fuel oil as found in EWI/prognos. Again, the EIA data already allows for the recent oil price developments, while EWI/prognos does not contain significant peaks. As for crude oil, both forecasts expect prices to fall towards 2010 and predict a subsequent moderate annual increase to 2030.

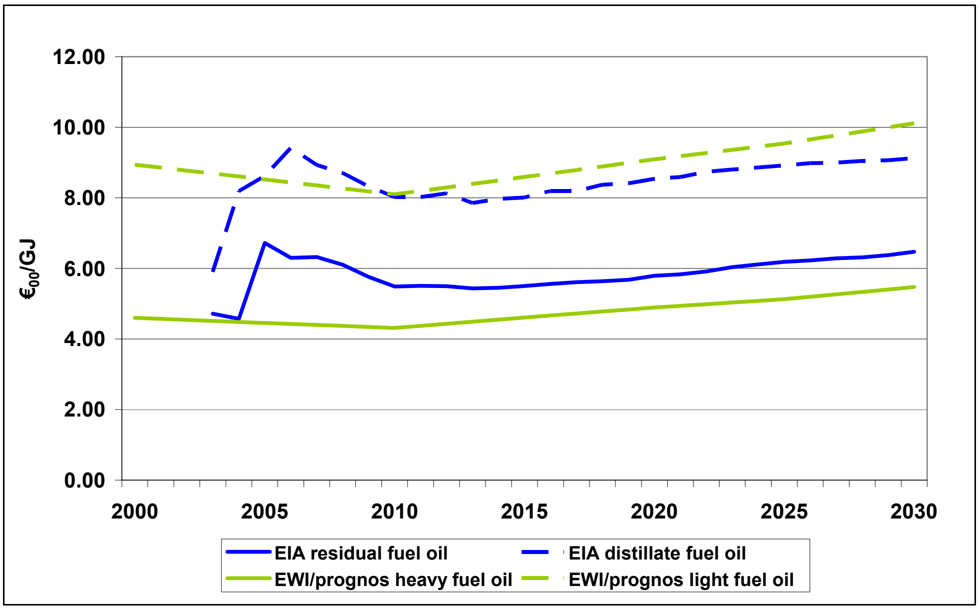

Figure 2-4: Price projections for other oil products from 2000 to 2030

Statistical evaluation of crude oil price projections

By calculating the arithmetic mean and the standard deviation (s), the different crude oil price projections can be analysed concerning their dispersion, which is illustrated in Figure 2-5. Therein, the curve of the arithmetic mean as well as the one sigma range[3] curves are shown, the latter limiting an area containing about two third of the projected prices. It can be observed that the IEA forecast exceeds this sigma range from 2008 on, while the WETO-H2 projection is situated on its lower limit. Further, the figure shows that the projections, after considerably spreading for the first decade (s = 1.13 in 2006), converge towards the end of the regarded time span (s = 0.60 in 2015; s = 0.29 in 2030). In terms of a percentage, the deviation from the arithmetic mean accounts for 16 % in 2006, 9 % in 2015 and finally 4 % in 2030.

[3] the one sigma range is defined by the values of one standard deviation below and one above the arithmetic mean

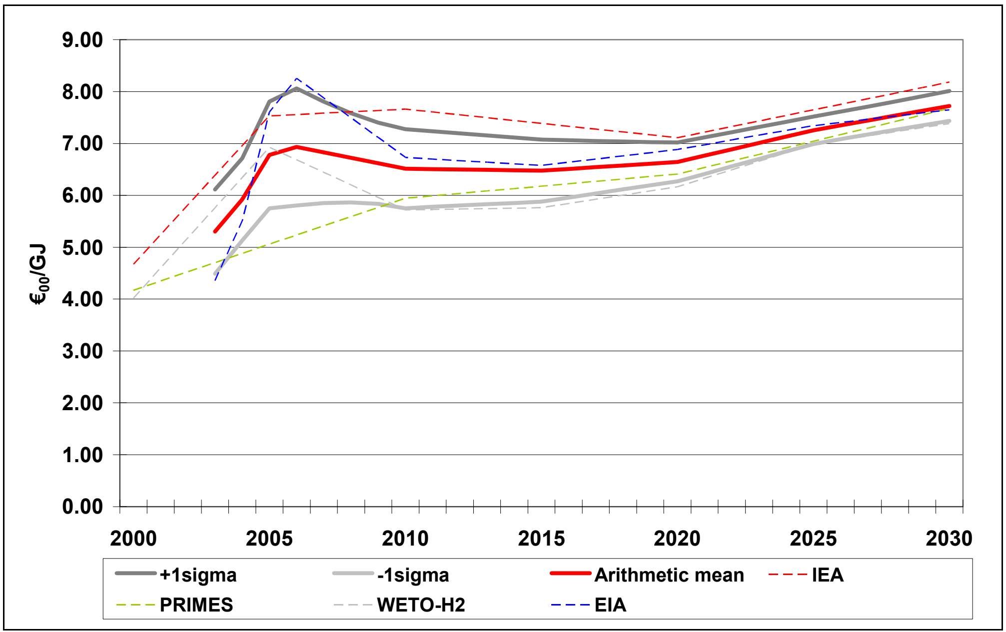

Figure 2-5: Statistical evaluation of price projections for crude oil

2.2.2 Prognoses on natural gas prices

As already mentioned in Chapter 2.1.2, projections for natural gas prices directly orientate on the crude oil price forecasts. Hence, Figure 2-4, which compares the natural gas price projections of all five sources of data, shows a course, which is qualitatively very similar to the one of Figure 2-2. It has to be outlined that EWI/prognos foresees a 2030 price level that is more than one Euro per GJ lower than the prices of all the other sources.

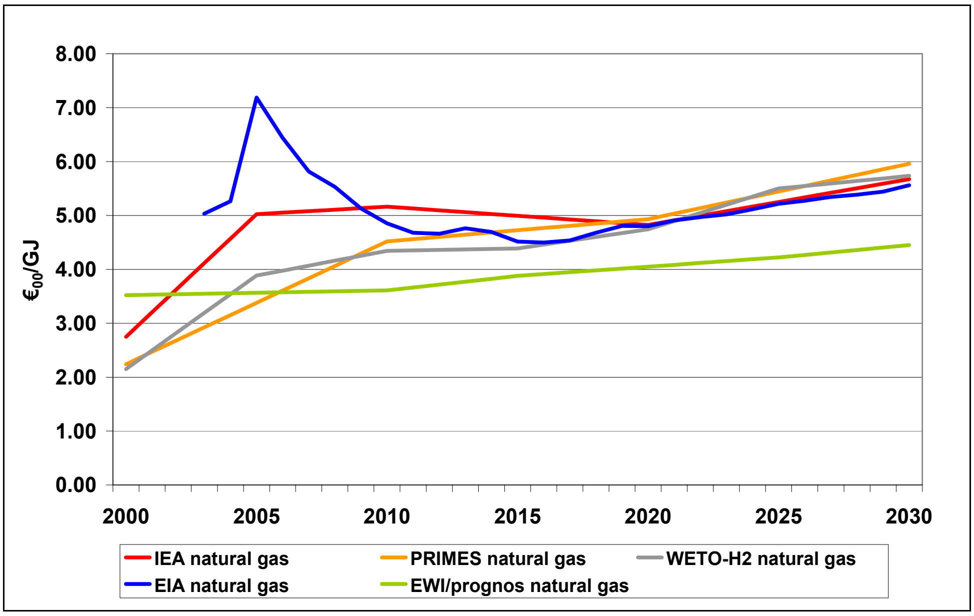

Figure 2-6: Comparison of natural gas price projections from 2000 to 2030

Statistical evaluation of natural gas price projections

In order to analyse the prognoses on natural gas prices, the same statistical parameters as for the crude oil price forecasts have been calculated. Figure 2-7 shows the resulting arithmetic mean and sigma range. For the first decade, there is also a high dispersion of the projections (s = 1.41 or 31 % of the arithmetic mean in 2005), followed by a convergency of the prices for the second decade (s = 0.37 or 8 % of the arithmetic mean in 2015). Finally, forecasts again deviate from the mean (s = 0.53 or 10 % of the arithmetic mean in 2030), which is quite remarkable in comparison the preceding analysis of crude oil prices. One reason for this might be that in the long-term, the natural gas price is assumed to become independent from the crude oil price by some sources. Another aspect could be deviating assumptions concerning the coalescence of the regional gas markets in the future.
The only projection that deviates significantly from the mean is the one of EWI/prognos, which is even below the sigma range.

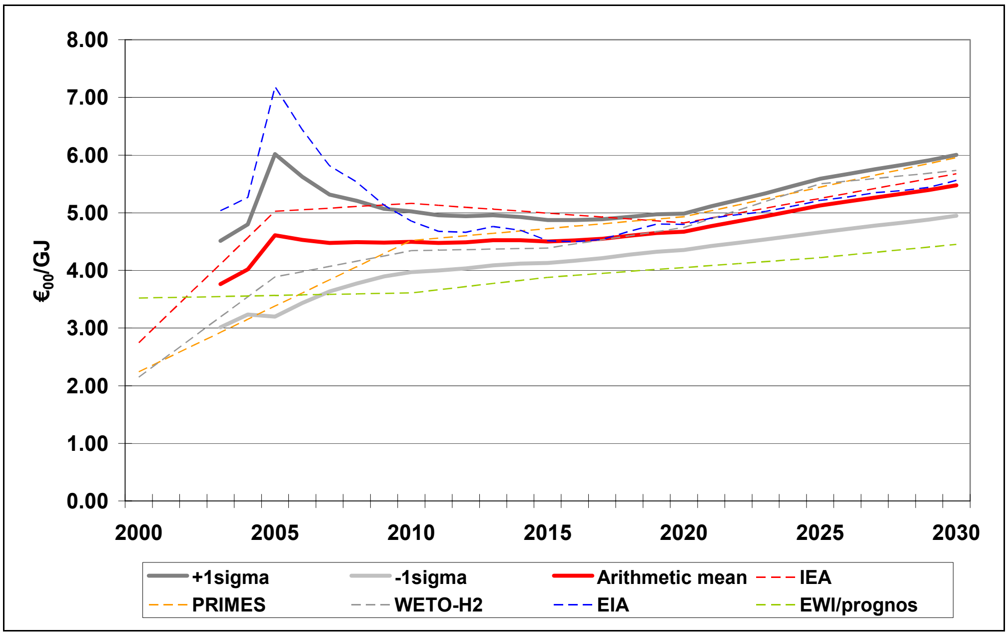

Figure 2-7: Statistical evaluation of price projections for natural gas

2.2.3 Prognoses on coal prices

Figure 2-5, which shows the different price projections for hard coal, underlines the tendencies that were identified in Chapter 2.1.3. After certain fluctuations in the first decade of the present century, which can be implicated to the global growth in energy demand, all sources of date expect the coal price to stabilise at a level of about 2 €/GJ, with a minor but steady growth towards 2030. The EIA prognosis forms the only case that shows a decline in the coal price by the end of the regarded time span.

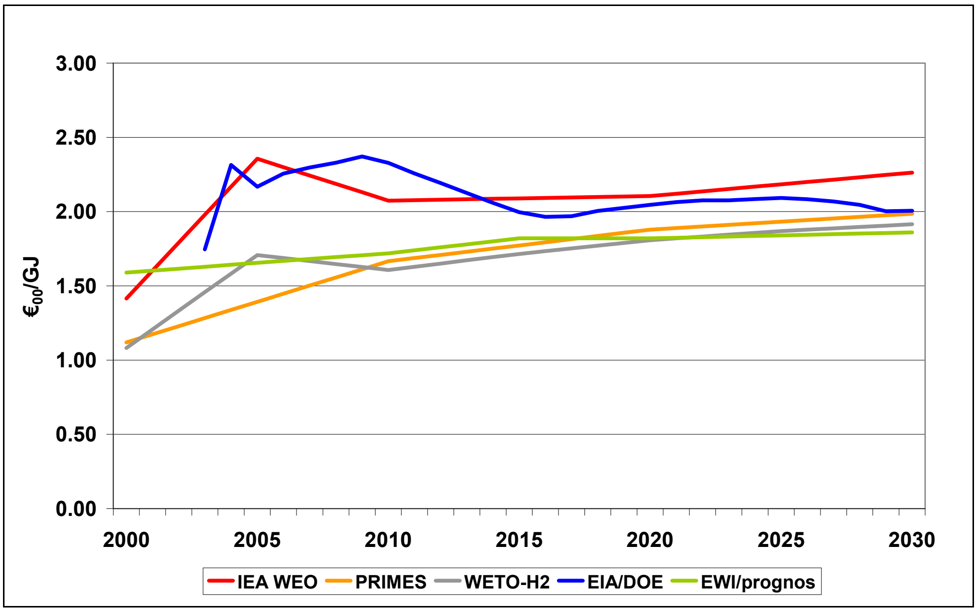

Figure 2-8: Comparison of coal price projections from 2005 to 2030

Statistical evaluation of coal price projections

In terms of coal price prognoses, the projections show a standard deviation of 0.35 in 2005 (19 % of the arithmetic mean) and 0.14 in 2015 (7.5 % of the arithmetic mean) which stays almost constant until 2030 (6.9 % of the arithmetic mean).

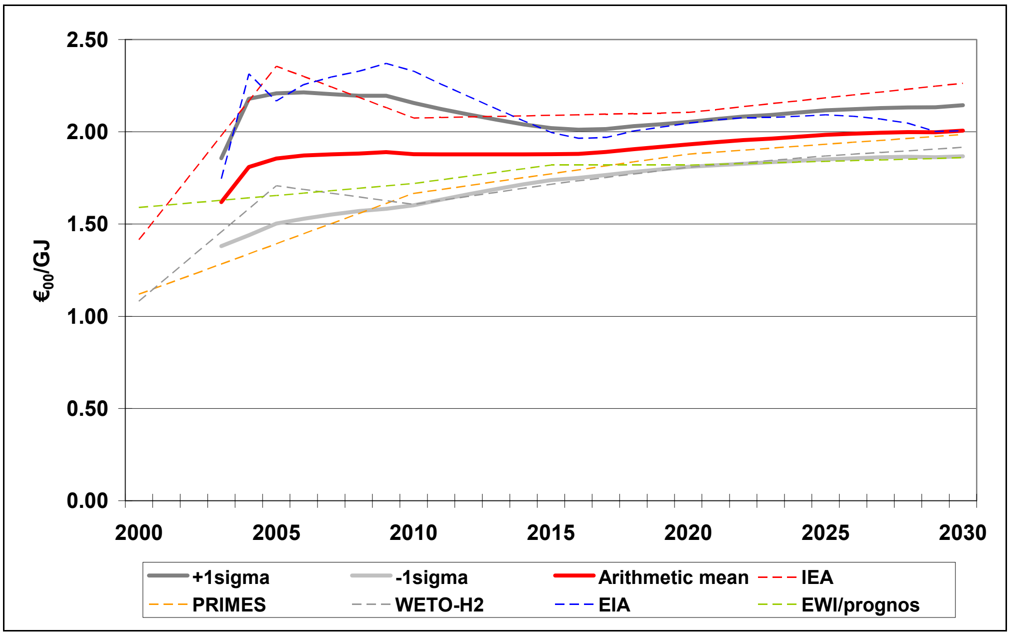

Figure 2-9: Statistical evaluation of price projections for coal

2.3 Nuclear fuel prices

2.3.1 Historical development

Whereas the price for nuclear fuel stayed at a moderate level throughout the last 20 years, the spot prices for uranium have undergone an impressive increase within the last five years (cf. Figure 2-13). This is most notably imputed to the rising demand for this fuel, together with the small number of producers worldwide and the limited mining capacities. Since nuclear power has zero greenhouse gas emissions, it is undergoing a renaissance for the electricity production in many countries.

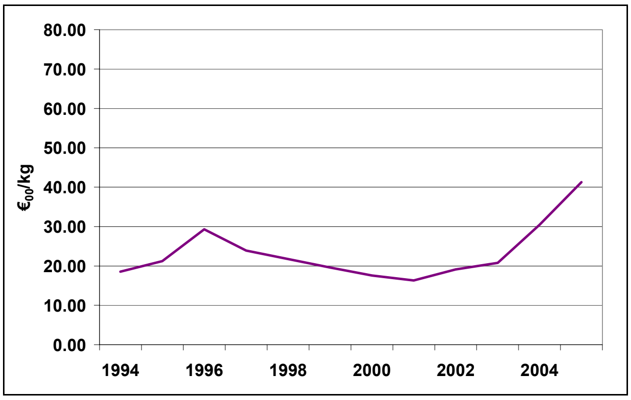

Figure 2-10: Development of the U.S. spot prices for nuclear fuel [EIA, 2006b]

2.3.2 Prognoses on nuclear fuel prices

Only one of the sources that were considered for the HYPOGEN modelling provides a forecast on nuclear fuel prices [WETO-H2, 2006]. It is illustrated in Figure 2-14, showing a growth in price for uranium of more than 160% from 2001 to 2030. This also reflects the assumption that global nuclear fuel resources are limited, while demand can be expected to grow under the influence of climate policies and the necessity of greenhouse gas emission reduction. To meet this higher demand, primary uranium production needs to rise sharply and new mines need to be developed, but this industry is still carrying risk from possible hazardous incidents or terrorist attacks which might let the demand and as a consequence the prices crash [Maeda, 2005].

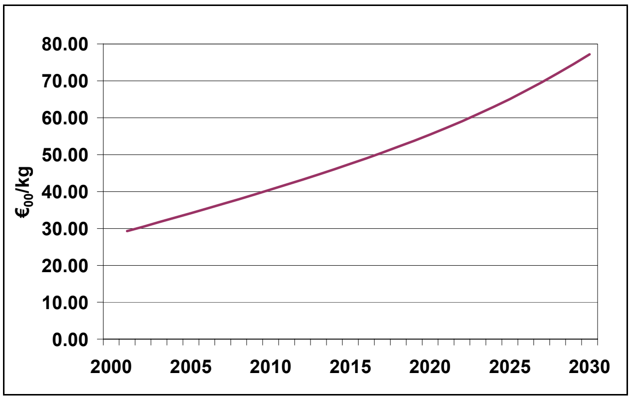

Figure 2-11: Projection for nuclear fuel prices according to [WETO-H2, 2006]

2.4 Conclusions for the modelling work

The preceding chapters have shown that, after the coalescence of projections for fuel prices in the near future, the projections of all forecasts for the long term level off in a curve describing the marginal costs of production. These costs of production generally are assumed to increase towards 2030 by means of higher costs for exploring and mining of unconventional resources.
It has to be outlined that the regarded projections deviate to different extents for each fuel, and that the forecasts on natural gas are showing the highest spreading from the mean in 2030. Insofar, and because of the rising importance of natural gas in electricity production, which can be expected to develop within the next decade, emphasis has to be put on the analysis of the influence of the future gas price development on the results of the modelling exercise.
Since fuel price forecasts are subject to high uncertainty, it is reasonable to consider different variants in the modelling work. For the reference scenario, it is recommended to use the arithmetic mean of the values published by the sources of data. Further, a high fuel price and a low fuel price case are proposed, representing the +1 sigma and -1 sigma values as introduced in Chapter 2.2.1. For nuclear fuel, the WETO-H2 projections on uranium prices are suggested to be used for the reference case, whereas a high and a low price case can be generated by adding and subtracting 10 % of the reference values, respectively.

Table 2-2: Proposed projections on fuel prices

Fuel		Unit	2005	2010	2020	2030
Crude oil	Baseline	€/GJ	6.78	6.51	6.64	7.72
	High Price	€/GJ	7.81	7.28	7.02	8.01
	Low Price	€/GJ	5.75	5.75	6.27	7.44
Natural gas	Baseline	€/GJ	4.61	4.50	4.67	5.48
	High Price	€/GJ	6.02	5.02	4.99	6.00
	Low Price	€/GJ	3.20	3.97	4.35	4.95
Coal	Baseline	€/GJ	1.86	1.88	1.93	2.01
	High Price	€/GJ	2.21	2.16	2.05	2.14
	Low Price	€/GJ	1.50	1.60	1.81	1.87
Uranium	Baseline	€/kg	34.16	40.53	55.45	77.21
	High Price	€/kg	37.58	44.58	61.00	84.93
	Low Price	€/kg	30.74	36.48	49.91	69.49

3 ELECTRICITY DEMAND PROJECTIONS

Next to the projections for primary energy prices, the second important set of framework data for the modelling of the European electricity market, the future electricity demand, is also subject to high uncertainty. In order to approach a probable future development, several macroeconomic factors can serve as indicators:

- Population development: growing population will lead to growth in electricity demand
- Economic growth: electricity demand will increase within a growing economy
- Structural change:
  (1) Switch from fossil fuels to electricity leads to growth in electricity demand

  (2) Development from industrial economies to economies with a stronger tertiary sector will decrease electricity demand since large-scale electricity intensive industries could be replaced by service enterprises

Obviously, the range of influence of the above-mentioned factors cannot be assessed easily. Hence, long-term forecasts are hardly published in literature.

3.1 Historical development and trends on the European electricity market

Indications for the future development of the European electricity demand can be derived from historical values, although the political development especially of Eastern Europe has to be considered as well. Table 3-1 underlines the different development in electricity consumption in EU 15 and in the new member states (EU 10). While EU 15 had a decrease in the annual average growth rates from 1995 to 2004, EU 10 increased its growth rates for electricity demand within this period, especially at the beginning of this century.

Table 3-1: Historical development of electricity demand in Europe [Eurostat, 2006]

Average annual growth	1985 - 1990	1990 - 1995	1995 - 2000	2000 - 2004	2003 - 2004
EU 15	2.73%	1.66%	2.52%	1.90%	1.67%
EU 10	n.a.	-2.03%	1.18%	1.93%	2.51%
EU 25 + NO	n.a.	1.26%	2.33%	1.82%	1.93%

It can further be observed that the fall of the Eastern Block caused a structural change in its former member states, which firstly led to a decrease in electricity demand, but subsequently paved the way to economic growth reflected by a rising consumption of electricity.
In 2004, the 25 members of the European Union together with Norway consumed a total of 2760 TWh electric energy [Eurostat, 2006]. More than 50 % of this amount was consumed by the dominating economies of Germany (18.6 %), France (15.1 %), and the United Kingdom (12.3 %) and Italy (10.7 %). The consumption of all European countries and Norway in 2004 is illustrated in Figure 3-1.

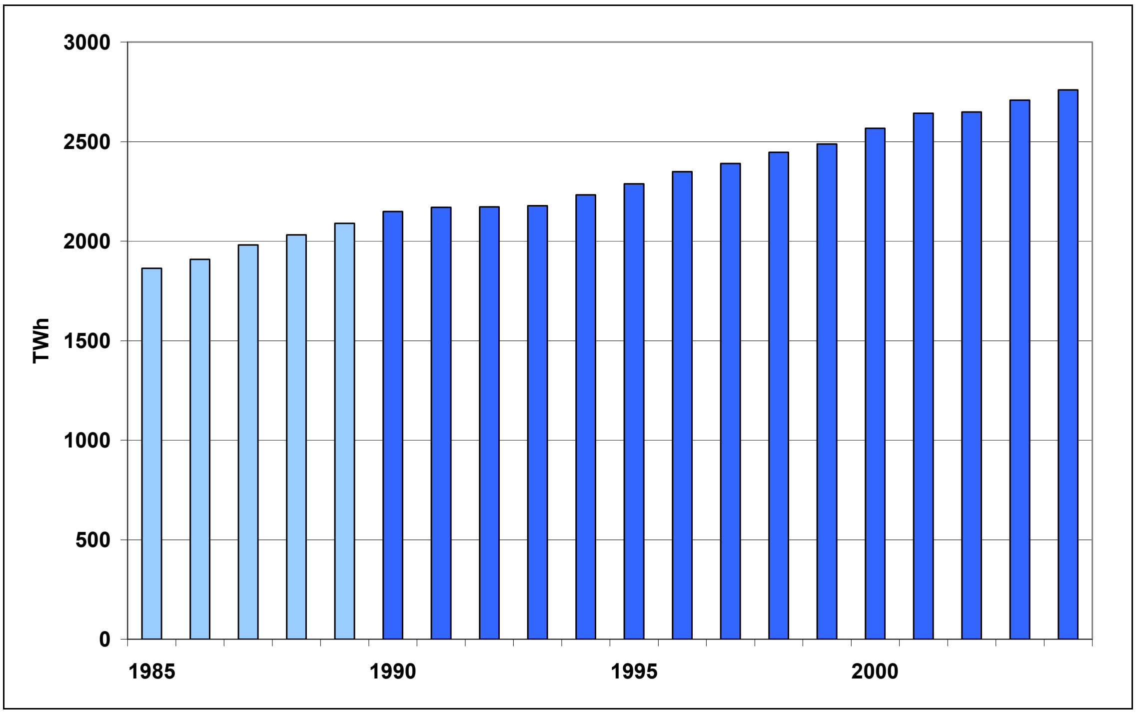

Figure 3-1: Development of total electricity demand in EU 25 + Norway from 1985 to 2004 (years 1985 – 1989 excluding Cyprus, Estonia, Latvia, Lithuania, Malta and Slovenia)

Regarding the recent growth rates (cf. Figure 3-3), the four big economies mentioned above had only a small average annual growth of electricity consumption in the antecedent years, which can be imputed to the influence of the minor economic growth in those countries, compared to the rest of Europe. Especially the Baltic Countries and the countries of the Iberian Peninsula showed high annual growth rates in electricity consumption. By contrast, demand in the Scandinavian countries – except for Finland – almost stayed unchanged.

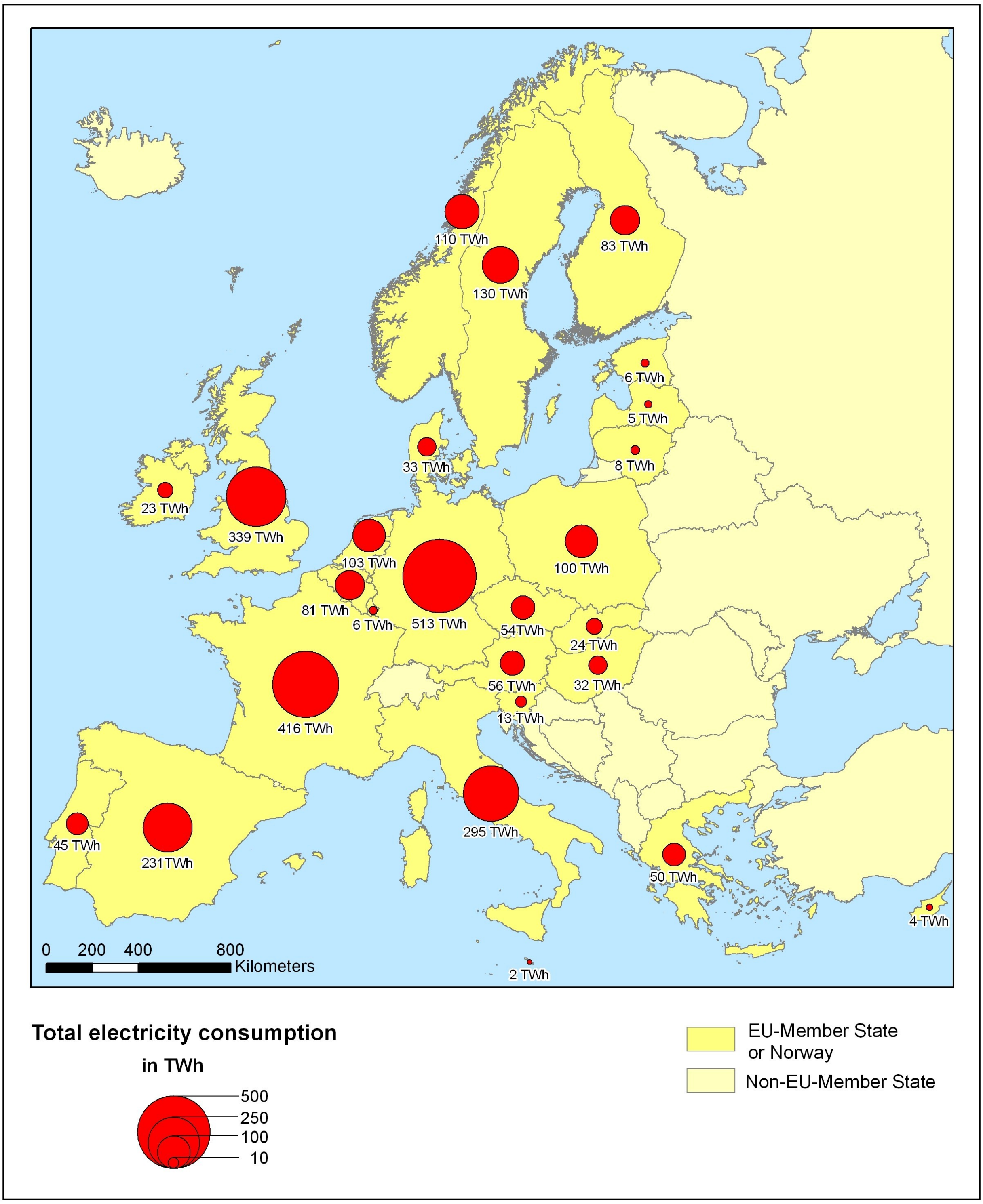

Figure 3-2: Electricity consumption in EU 25 and Norway in 2004

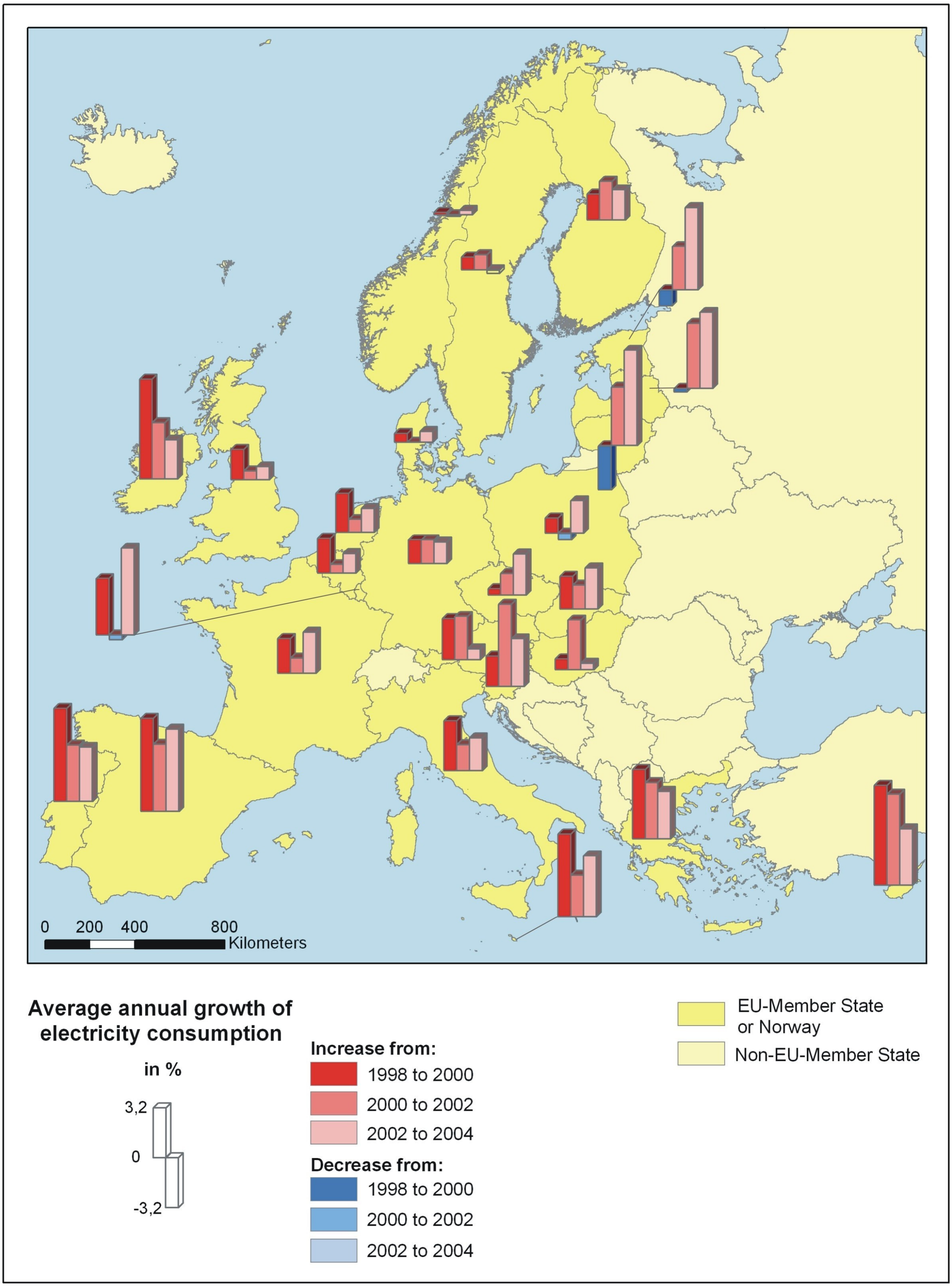

Figure 3-3: Average annual growth rates of electricity consumption in EU 25 and Norway

3.2 The PRIMES projections on electricity demand in Europe

The projections on the development of electricity demand[4] made for the baseline case [Capros et al., 2006] in the PRIMES study foresee an average annual growth rate from 2000 to 2030 of 1.54 % in the European Union plus Norway and Switzerland (cf. Table 3-2). The corresponding rate for the EU 25 members accounts for 1.51 % per annum. At the same time, the total EU 25 gross domestic product is assumed to growth by 1.97 % annual average (cf. Figure 3-4).

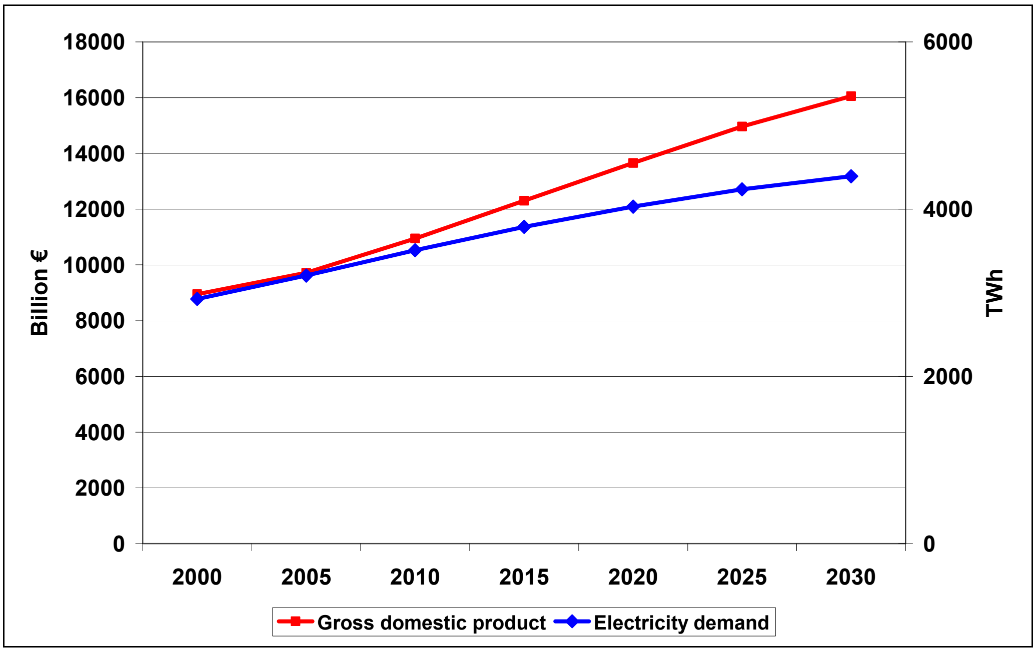

Figure 3-4: Development of GDP and electricity demand in EU 25 as projected in PRIMES

Comparing the country-specific growth rates of electricity demand, the trend that was identified in the preceding chapter is continued largely: the states of the Iberian Peninsula together with the Baltic Countries and further new EU member states are assumed to show growth in electricity demand of more than 2 % annual average. Amongst those countries that are presumed to show an average annual growth of about or less than 1 % are again the Scandinavian countries and the most important EU 15 economies of Germany, France and the United Kingdom. The electricity demand of Belgium and Switzerland are neither predicted to grow more than about one percent per annum within the 2000 to 2030 period.
The second scenario from the PRIMES study that was taken into consideration for the model framework data forms the efficiency energy case which takes into account all efficiency policies tabled by the European Commission. Within it, electricity demand in Europe is expected to show significantly lower growth rates than in the baseline case, resulting in an average annual growth rate of 0.62 % from 2000 to 2030 in EU 25 (cf. Table 3-2). Final electricity consumption in 2030 in the efficiency case is 23.8 % lower than in the baseline case. Electricity demand projections assumed in further scenarios that were analysed within the PRIMES study[5] are included in the range of the two above cases, which tend to be rather high in the baseline case and low in the efficiency case, respectively.

4 excluding auto-consumption and transmission and distribution losses
5 supplementary projections on electricity demand assumed from PRIMES scenarios can be found in the Appendix

Table 3-2: Electricity demand forecasts as assumed in the PRIMES study (in ascending order of presumed average annual growth rate in the Baseline case)

Country	Baseline scenario					Efficiency scenario				
	2005 [TWh]	2010 [TWh]	2020 [TWh]	2030 [TWh]	Average annual growth rate 2000 - 2030	2005 [TWh]	2010 [TWh]	2020 [TWh]	2030 [TWh]	Average annual growth rate 2000 - 2030
Austria	64	74	84	90	1.84%	64	70	70	69	0.98%
Belgium	84	91	100	105	1.02%	84	88	88	87	0.37%
Cyprus	4	5	6	6	2.54%	4	4	4	4	1.09%
Czech Rep.	53	62	76	88	1.94%	53	59	59	59	0.61%
Denmark	33	35	38	40	0.71%	33	33	30	32	-0.05%
Estonia	6	8	11	13	3.22%	6	7	8	9	2.11%
Finland	84	91	101	105	1.11%	84	88	83	81	0.23%
France	426	457	509	549	1.19%	426	443	439	422	0.30%
Germany	508	542	593	629	0.89%	508	525	501	499	0.12%
Greece	54	62	74	81	2.12%	54	59	60	57	0.92%
Hungary	33	42	58	66	2.74%	33	40	45	46	1.48%
Ireland	24	28	35	39	2.20%	24	26	27	27	1.03%
Italy	302	338	418	477	1.88%	302	325	362	378	1.10%
Latvia	6	8	13	17	4.66%	6	7	10	11	3.20%
Lithuania	8	10	15	19	3.79%	8	10	12	14	2.71%
Luxembourg	6	7	8	9	1.70%	6	7	8	8	1.21%
Malta	2	2	3	3	1.97%	2	2	2	3	1.34%
Netherland	106	115	135	147	1.36%	106	111	113	109	0.37%
Norway	117	123	139	154	1.06%	n.a.	n.a.	n.a.	n.a.	n.a.
Poland	102	121	180	236	3.01%	102	117	144	159	1.67%
Portugal	46	56	74	85	2.67%	46	50	53	54	1.14%
Slovakia	26	30	42	53	2.99%	26	29	36	40	1.99%
Slovenia	14	16	19	21	2.35%	14	15	16	16	1.51%
Spain	243	292	345	376	2.33%	243	284	297	297	1.53%
Sweden	132	137	151	156	0.65%	132	134	133	127	-0.04%
Switzerland	57	59	64	73	0.94%	n.a.	n.a.	n.a.	n.a.	n.a.
Utd. Kingdom	353	386	436	474	1.22%	353	373	358	349	0.19%
EU 25	**2718**	**3015**	**3522**	**3884**	**1.54%**	**2718**	**2910**	**2959**	**2958**	**0.62%**
EU 25+NO+CH	2892	3198	3726	4111	1.51%	n.a.	n.a.	n.a.	n.a.	n.a.

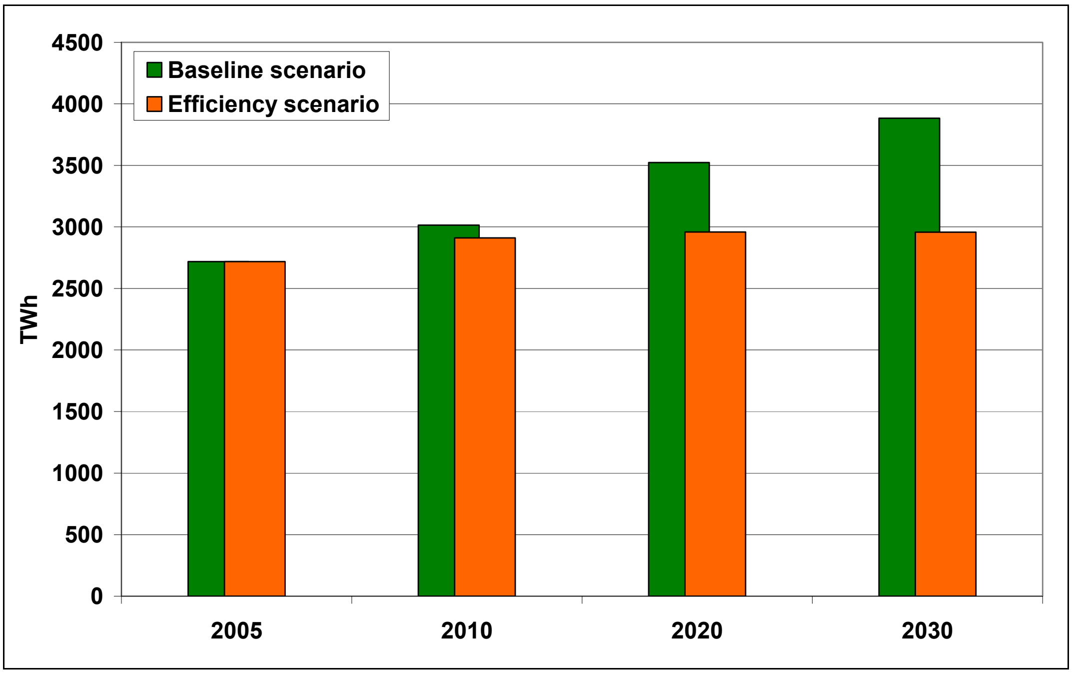

Figure 3-5: Comparison of electricity demand projections in the PRIMES scenarios

3.3 Other projections

Supplementing the growth rates resulting from the PRIMES projections, values published by [IEA, 2006] and [EIA, 2006c] shall be mentioned here. The IEA World Energy Outlook only provides forecasts on the global electricity demand, which is assumed to grow by 2.6 % average per annum between 2004 and 2030. This figure, however, is mainly made up by the growth in the developing countries, most notably China and India. The consumption of these countries is supposed to increase three times faster than the one of the OECD countries. In order to approach a comparable value for the European growth rates for electricity demand, the presumed electricity production can be applied: it accounts for 1.2 % average annual growth from 2004 to 2030. This figure is also published by EIA, referring to the average annual growth in electricity demand in the European OECD countries from 2003 to 2030.

3.4 Conclusions for the modelling work

All the sources of data presume that future growth rates of electricity demand in Europe 25, Norway and Switzerland will be noticeably lower than the historical values. Furthermore, the development of electricity demand is projected to uncouple increasingly from economic growth and the GDP, respectively, resulting in lower growth rates for electricity demand.
For the modelling work, it is recommended to utilise the PRIMES baseline projections on electricity demand as a high growth case and the PRIMES efficiency projections as a low growth case. As reference values, it is proposed to use the arithmetic mean resulting from those two cases as shown in Table 3-3.

Table 3-3: Proposed projections on electricity demand from 2000 to 2030 (in ascending order of average annual growth rate)

Country	2000 [TWh]	2005 [TWh]	2010 [TWh]	2015 [TWh]	2020 [TWh]	2025 [TWh]	2030 [TWh]	Average annual growth rate 2000-2030
Sweden	129	132	136	140	142	141	142	0.32%
Denmark	32	33	34	33	34	35	36	0.35%
Germany	483	508	534	549	547	557	564	0.52%
Finland	75	84	90	92	92	92	93	0.70%
Belgium	78	84	90	93	94	95	96	0.71%
Utd. Kingdom	329	353	380	397	397	403	411	0.74%
France	385	426	450	465	474	479	485	0.77%
Netherland	98	106	113	120	124	125	128	0.90%
Cz. Republic	49	53	61	66	67	71	73	1.33%
Austria	52	64	72	76	77	78	79	1.44%
Luxembourg	6	6	7	7	8	8	9	1.46%
Italy	272	302	331	363	390	411	428	1.51%
Greece	43	54	61	65	67	68	69	1.57%
Ireland	20	24	27	30	31	32	33	1.66%
Malta	2	2	2	2	3	3	3	1.67%
Cyprus	3	4	5	5	5	5	5	1.89%
Spain	188	243	288	311	321	329	337	1.95%
Slovenia	11	14	16	17	18	18	19	1.96%
Portugal	38	46	53	60	64	67	69	1.99%
Hungary	29	33	41	48	52	54	56	2.17%
Poland	97	102	119	142	162	181	197	2.41%
Slovakia	22	26	30	35	39	43	46	2.52%
Estonia	5	6	8	9	9	10	11	2.71%
Lithuania	6	8	10	12	13	15	16	3.29%
Latvia	4	6	8	10	12	13	14	4.00%
EU 25	**2458**	**2718**	**2963**	**3145**	**3241**	**3333**	**3421**	**1.11%**

4 PROJECTIONS ON THE DEVELOPMENT OF CLIMATE POLICY

In the Kyoto Protocol to the United Nations Framework Convention on Climate Change, the member states of the European Union pledged themselves to reduce the total amount of greenhouse gas emissions to a level of 8 % lower than the emissions of the base year[6] by the 2008 - 2012 commitment period. One instrument to achieve this goal was the introduction of the European Union Emissions Trade Scheme [EU, 2003], which started on the 1st January 2005 and is supposed to realise the committed targets in the most cost-effective way.
So far, the model framework data concerning greenhouse gas emission limits can be clearly estimated, in contrast to the preceding factors of energy prices and electricity demand. However, prognoses beyond the Kyoto commitment period are even more uncertain than other projections, since emission reduction presently and in the near future will only be determined by worldwide political decision instead of macroeconomic factors.

4.1 Climate change and the necessity of emission reduction

Man made climate change is presently discussed intensively in politics and in public, since extreme weather conditions like storms, heat waves or droughts seem to have accumulated and intensified within the last decade. According to the Intergovernmental Panel on Climate Change (IPCC), "the global average surface temperature has increased over the 20th century by about 0.6°C" [Albritton et al., 2001]. Furthermore, in the IPCC emissions scenarios prepared for the assessment of the impact of social, economic and technological developments on emission trends without explicit climate policy interventions [Nakicenovic et al., 2000], the globally averaged surface temperature is projected to increase by 1.4 to 5.8°C within the 21st century. This temperature rise, however, would exceed the tolerable limit of 2°C [Graßl et al., 2003], with possibly devastating consequences:

- continuation of snow cover and ice extent decrease and permafrost melting
- rise of global average sea level and increase in ocean heat content
- amplification of impacts from extreme weather conditions
- spread of diseases, starvation and underfeeding in disadvantaged regions [WHO, 2002]

As global warming is most of all attributable to human activities [Albritton et al., 2001], namely the burning of fossil fuels, greenhouse gas mitigation has to be brought forward by global reduction policies as initiated by the United Nations Conference on Environment and Development in Rio de Janeiro, 1992 and as – at least partially – implemented by the Kyoto Protocol in 2005. Since those agreements only foresee reduction measures until 2012 and several main greenhouse gas-emitting nations did not join them, the exigency for long-term global mitigation policies is evident.
The following chapter is meant to give an overview on the existing national targets for greenhouse gas emission reduction of Germany, Switzerland and the United Kingdom, which form the basis for the model assumptions on carbon dioxide emission limits until 2030.

[6] 1990 in most of the European countries; exceptions are Hungary (average of 1985-1987), Slovenia (1986) and Poland (1988) [EC, 2004b]

4.2 Reduction targets in politics

Since global consensus on emission reduction objectives seems inaccessible at present, indications for mid- and long-term greenhouse gas emission limits have to be extracted from national and European publications, as far as they are defined.

4.2.1 Emissions policy in Germany

The final report on Sustainable Energy Supply under the Conditions of Globalisation and Liberalisation delivered by the German Parliament by the Enquête Commission in 2002 amongst other gives recommendation on future activities concerning mid- and long-term climate protection targets. According to this report, the German government should – in addition to the perpetuation of short-term emission reduction targets – aim at ambitious mid- and long-term national mitigation. Hence, Germany's domestic greenhouse gas emissions should be reduced by 40 % until 2020, compared to the 1990 basis. The commission further recommends that Germany should act as a positive national example and orientate on long-term mitigation of 80 % of the emissions by 2050 [Enquête, 2002].

4.2.2 Emissions policy in Switzerland

Although not member of the European Union, Switzerland and its national policies as well as Swiss domestic pre-policy documents could serve as source of evidence for future climate policy targets. By ratifying the Kyoto protocol, Switzerland committed to reduce its domestic carbon dioxide emissions of 1990 by 10 % until the 2008 - 2012 period, which means a total amount of 242.65 Mt or about 32.5 t CO_2 per capita, assuming the 2005 population of 7.46 Million people [Swissworld, 2006]. According to the idea of the "2000 Watt Society", a vision that was developed within the frame of the Novatlantis program of the ETH domain [Spreng & Semadeni, 2001], the long-term emission target for Switzerland should be one ton of CO_2 per capita. This aim could be reached by the second half of this century or at the latest by the fist half of the next century [Novatlantis, 2006].
It has to be remarked made that in the Swiss electricity sector, the per-capita amount of CO_2 emitted in electricity production is comparably low, since it is based on hydro and nuclear power. Insofar, mitigation measures will have to be fortified to a higher extent in other sectors such as manufacturing, transport or households.

4.2.3 Emissions policy in the United Kingdom

The Department of Trade and Industry (DTI) coordinated the development of the United Kingdom's position on future energy policy and published the White Paper "Our energy future – creating a low carbon economy" in 2003. Therein, it is underlined that UK government will "continue to work with other countries to establish both a consensus around the need for change and firm commitments to take action to reduce carbon emissions world wide within the framework of the UNFCCC" [DTI, 2003].
Concretely, the UK policy formulated in the White Paper aims at reducing the United Kingdom's 1990 base CO_2 emission by 20 % until the 2008 – 2012 commitment period. This target exceeds the obligation derived from the Kyoto Protocol and the EU burden sharing of 12.5 %. Further, the department considers a worldwide greenhouse gas emission reduction of 60 % compared to the present amount as necessary by 2050, and is determined to realise this goal in the United Kingdom in order to demonstrate leadership in the international process of climate protection.

4.3 Conclusions for the modelling work

In contrast to the projections for primary energy prices and electricity demand, there are no international or European prognoses available on the development of greenhouse gas emission reduction requirements beyond 2012. Looking at national publications on mitigation targets, on can find ambitious reduction rates of 60 % reduction in the United Kingdom and 80 % reduction in Germany by 2050. It can be assumed that an international consensus would probably reach lower emission reduction target, and the stagnant development in policy that could be observed in the results of the United Nations Climate Change Conference in Nairobi in Fall 2006 gives reason to some doubt that any global emission policy coulg be implemented beyond 2012.
For the HYPOGEN modelling, it is proposed to use emissions reduction targets of 20 % until 2020 and 30 % until 2030 f compared to the total European base value[7] or the electricity sector, assuming that the European Union ultimately would continue its path of emission mitigation independently from global agreements.

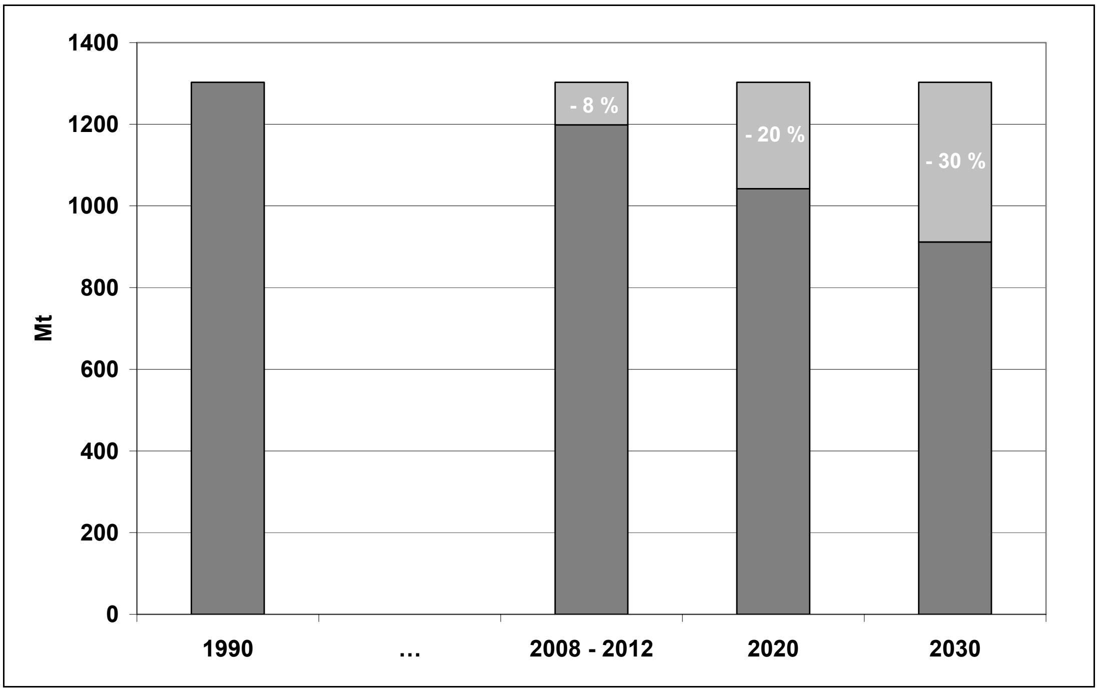

Figure 4-1: Proposed development of greenhouse gas emissions in EU 25 plus Norway and Switzerland until 2030

[7] EU 25 plus Norway and Switzerland

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6 ANNEX

Table 6-1: PRIMES projections on electricity demand in the No Carbon Constraint Scenario (in TWh)

	2000	2005	2010	2015	2020	2025	2030	Average annual growth rate
Austria	43	46	52	65	74	80	84	1.84%
Belgium	58	69	78	84	91	96	100	1.01%
Cyprus	2	2	3	4	5	6	6	2.55%
Czech Republic	48	48	50	54	62	69	75	1.87%
Denmark	29	31	33	33	35	37	39	0.80%
Estonia	7	4	5	7	8	9	11	3.21%
Finland	59	66	76	85	91	96	101	1.10%
France	303	344	386	427	458	484	510	1.18%
Germany	448	454	484	510	541	570	593	0.87%
Greece	29	34	43	54	62	68	74	2.11%
Hungary	32	28	30	33	42	51	58	2.74%
Ireland	12	15	20	24	27	31	34	2.17%
Italy	215	239	274	303	338	379	418	1.88%
Latvia	9	4	4	6	8	11	13	4.66%
Lithuania	12	6	6	8	10	13	14	3.73%
Luxembourg	4	5	6	6	7	8	8	1.68%
Malta	1	1	2	2	2	3	3	1.98%
Netherlands	74	83	98	106	115	125	135	1.37%
Poland	96	90	97	102	121	150	181	3.03%
Portugal	24	29	39	46	56	66	74	2.67%
Slovakia	23	22	22	26	30	36	42	2.96%
Slovenia	10	9	11	14	16	18	19	2.35%
Spain	126	141	189	244	292	324	346	2.33%
Sweden	121	125	129	133	138	144	150	0.64%
United Kingdom	275	295	331	354	386	413	437	1.21%
Bulgaria	35	29	24	25	28	32	37	2.27%
Romania	50	36	34	43	56	72	85	4.09%
Norway	97	104	110	113	121	128	135	0.89%
Switzerland	47	49	53	55	60	66	72	1.31%
EU25	**2060**	**2192**	**2467**	**2728**	**3015**	**3285**	**3526**	**1.53%**
EU25+NO+CH	2204	2345	2629	2896	3196	3479	3733	1.50%
EU27	2145	2257	2525	2797	3099	3389	3649	1.59%
EU27+NO+CH	2290	2410	2688	2965	3280	3583	3856	1.56%

Table 6-2: PRIMES projections on electricity demand in the Low Carbon Constraint without CCS Scenario (in TWh)

	2000	2005	2010	2015	2020	2025	2030	Average annual growth rate
Austria	43	46	52	65	74	80	85	1.85%
Belgium	58	69	78	84	92	97	101	0.99%
Cyprus	2	2	3	4	5	6	6	2.54%
Czech Republic	48	48	50	54	60	67	74	1.85%
Denmark	29	31	33	33	35	37	39	0.79%
Estonia	7	4	5	7	8	9	10	3.14%
Finland	59	66	76	85	91	96	100	1.09%
France	303	344	386	427	461	490	517	1.22%
Germany	448	454	484	510	539	567	588	0.82%
Greece	29	34	43	54	61	66	71	2.03%
Hungary	32	28	30	33	42	51	58	2.73%
Ireland	12	15	20	24	27	31	34	2.16%
Italy	215	239	274	303	337	376	415	1.85%
Latvia	9	4	4	6	8	11	13	4.65%
Lithuania	12	6	6	8	10	12	15	3.76%
Luxembourg	4	5	6	6	7	8	8	1.69%
Malta	1	1	2	2	2	3	3	1.97%
Netherlands	74	83	98	106	114	125	134	1.35%
Poland	96	90	97	102	118	145	175	2.90%
Portugal	24	29	39	46	55	65	73	2.63%
Slovakia	23	22	22	26	30	36	42	2.96%
Slovenia	10	9	11	14	16	17	19	2.32%
Spain	126	141	189	244	291	322	344	2.32%
Sweden	121	125	129	133	139	145	151	0.63%
United Kingdom	275	295	331	354	383	409	433	1.20%
Bulgaria	35	29	24	25	27	31	36	2.23%
Romania	50	36	34	43	56	70	84	3.99%
Norway	97	104	110	113	122	130	136	0.91%
Switzerland	47	49	53	55	61	67	72	1.35%
EU25	**2060**	**2192**	**2467**	**2728**	**3004**	**3269**	**3509**	**1.51%**
EU25+NO+CH	2204	2345	2629	2896	3188	3465	3717	1.48%
EU27	2145	2257	2525	2797	3087	3371	3628	1.56%
EU27+NO+CH	2290	2410	2688	2965	3270	3567	3837	1.54%

Table 6-3: PRIMES projections on electricity demand in the Low Carbon Constraint with CCS Scenario (in TWh)

	2000	2005	2010	2015	2020	2025	2030	Average annual growth rate
Austria	43	46	52	65	74	80	85	1.85%
Belgium	58	69	78	84	92	97	101	0.99%
Cyprus	2	2	3	4	5	6	6	2.54%
Czech Republic	48	48	50	54	60	67	74	1.85%
Denmark	29	31	33	33	35	37	39	0.79%
Estonia	7	4	5	7	8	9	10	3.14%
Finland	59	66	76	85	91	96	100	1.09%
France	303	344	386	427	461	490	517	1.22%
Germany	448	454	484	510	539	567	588	0.82%
Greece	29	34	43	54	61	66	71	2.03%
Hungary	32	28	30	33	42	51	58	2.73%
Ireland	12	15	20	24	27	31	34	2.16%
Italy	215	239	274	303	337	376	415	1.85%
Latvia	9	4	4	6	8	11	13	4.65%
Lithuania	12	6	6	8	10	12	15	3.76%
Luxembourg	4	5	6	6	7	8	8	1.69%
Malta	1	1	2	2	2	3	3	1.97%
Netherlands	74	83	98	106	114	125	134	1.35%
Poland	96	90	97	102	118	145	175	2.90%
Portugal	24	29	39	46	55	65	73	2.63%
Slovakia	23	22	22	26	30	36	42	2.96%
Slovenia	10	9	11	14	16	17	19	2.32%
Spain	126	141	189	244	291	322	344	2.32%
Sweden	121	125	129	133	139	145	151	0.63%
United Kingdom	275	295	331	354	383	409	433	1.20%
Bulgaria	35	29	24	25	27	31	36	2.23%
Romania	50	36	34	43	56	70	84	3.99%
Norway	97	104	110	113	122	130	136	0.91%
Switzerland	47	49	53	55	61	67	72	1.35%
EU25	**2060**	**2192**	**2467**	**2728**	**3004**	**3269**	**3508**	**1.51%**
EU25+NO+CH	2204	2345	2629	2896	3188	3465	3717	1.48%
EU27	2145	2257	2525	2797	3087	3371	3628	1.56%
EU27+NO+CH	2290	2410	2688	2965	3270	3567	3837	1.54%

Table 6-4: PRIMES projections on electricity demand in the High Carbon Constraint without CCS Scenario (in TWh)

	2000	2005	2010	2015	2020	2025	2030	Average annual growth rate
Austria	52	65	74	81	86	89	92	1.91%
Belgium	78	84	92	99	104	105	104	0.98%
Cyprus	3	4	5	5	6	6	6	2.50%
Czech Republic	50	54	60	65	71	78	82	1.70%
Denmark	33	33	35	36	39	39	41	0.77%
Estonia	5	7	8	9	10	11	12	3.01%
Finland	76	85	91	95	99	98	99	0.89%
France	386	427	461	498	534	555	569	1.30%
Germany	484	510	539	568	588	603	614	0.79%
Greece	43	54	61	65	69	74	78	1.96%
Hungary	30	33	42	50	58	63	66	2.74%
Ireland	20	24	27	31	35	37	39	2.18%
Italy	274	303	337	373	410	444	468	1.81%
Latvia	4	6	8	11	13	16	17	4.64%
Lithuania	6	8	10	12	14	16	18	3.70%
Luxembourg	6	6	7	8	9	9	10	1.73%
Malta	2	2	2	3	3	3	3	1.95%
Netherlands	98	106	114	123	132	140	138	1.14%
Poland	97	102	118	139	170	201	225	2.85%
Portugal	39	46	55	65	72	79	83	2.58%
Slovakia	22	26	30	36	43	48	53	2.98%
Slovenia	11	14	16	17	19	20	21	2.33%
Spain	189	244	291	320	344	361	376	2.32%
Sweden	129	133	139	145	151	154	156	0.64%
United Kingdom	331	354	383	408	435	460	475	1.22%
Bulgaria	24	25	27	32	35	40	46	2.15%
Romania	34	43	56	69	83	94	105	3.84%
Norway	110	113	122	131	139	144	147	0.98%
Switzerland	53	55	61	67	74	79	81	1.44%
EU25	**2467**	**2728**	**3004**	**3263**	**3513**	**3712**	**3847**	**1.49%**
EU25+NO+CH	2629	2896	3187	3462	3726	3935	4075	1.47%
EU27	2525	2797	3086	3364	3631	3847	3998	1.54%
EU27+NO+CH	2688	2965	3269	3563	3845	4070	4226	1.52%

Table 6-5: PRIMES projections on electricity demand in the High Carbon Constraint with CCS Scenario (in TWh)

	2000	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**Average annual growth rate**
Austria	43	46	52	65	74	81	86	1.90%
Belgium	58	69	78	84	91	98	104	1.06%
Cyprus	2	2	3	4	5	5	6	2.50%
Czech Republic	48	48	50	54	59	64	71	1.75%
Denmark	29	31	33	33	34	36	39	0.78%
Estonia	7	4	5	7	8	9	10	3.08%
Finland	59	66	76	85	91	95	99	0.92%
France	303	344	386	427	461	497	534	1.30%
Germany	448	454	484	510	531	560	587	0.80%
Greece	29	34	43	54	61	64	69	1.94%
Hungary	32	28	30	33	42	50	58	2.75%
Ireland	12	15	20	24	27	31	34	2.19%
Italy	215	239	274	303	334	370	411	1.83%
Latvia	9	4	4	6	8	11	13	4.64%
Lithuania	12	6	6	8	10	12	14	3.70%
Luxembourg	4	5	6	6	7	8	9	1.73%
Malta	1	1	2	2	2	3	3	1.95%
Netherlands	74	83	98	106	114	123	132	1.16%
Poland	96	90	97	102	117	139	170	2.89%
Portugal	24	29	39	46	55	64	73	2.61%
Slovakia	23	22	22	26	30	36	43	3.00%
Slovenia	10	9	11	14	16	17	19	2.33%
Spain	126	141	189	244	290	319	344	2.31%
Sweden	121	125	129	133	139	145	151	0.64%
United Kingdom	275	295	331	354	380	406	434	1.24%
Bulgaria	35	29	24	25	27	31	36	2.21%
Romania	50	36	34	43	55	69	85	4.03%
Norway	97	104	110	113	122	131	139	0.98%
Switzerland	47	49	53	55	61	67	74	1.44%
EU25	**2060**	**2192**	**2467**	**2728**	**2983**	**3243**	**3511**	**1.51%**
EU25+NO+CH	2204	2345	2629	2896	3166	3442	3724	1.49%
EU27	2145	2257	2525	2797	3065	3344	3632	1.56%
EU27+NO+CH	2290	2410	2688	2965	3248	3542	3845	1.54%