Wuppertal Institute
for Climate, Environment and Energy

Development of Alternative Energy & Climate Scenarios for the Czech Republic

Final Report

By order of the coalition of Czech environmental NGOs lead by Friends of the Earth Czech Republic

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Final Report

Hnutí DUHA – Friends of the Earth Czech Republic campaigns for environmental solutions on a wide range of issues, with priorities in energy and climate, forests, nature conservation, waste and resources and agriculture, as well as on general environmental policy issues.

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1 Introduction

1.1 Background to the study

Energy policy together with climate policy has emerged as a core policy field. The current discussions about peak oil, security of (conventional) energy supply and climate change highlight the relevance of this field in relation to some of the most urgent problems of national and international policy development.

With this background the Czech environmental NGOs on the one hand need a structured outlook over the possible future development of the Czech energy system, in order to structure and quantify the potentials and barriers to a more sustainable policy in the field of energy use and supply and to analyse the implications of current and potential future political initiatives. On the other hand they need a clear and informed foundation as a background for their political demands.

This study provides a detailed modelling and description of possible future developments of the Czech energy system through the formulation of three scenarios with a time horizon to 2050. The main results of the study include carbon dioxide emissions, the use of different primary energy carriers for electricity and heat production as well as fuel used for transportation.

1.2 Aims of the study

The model methodology, assumptions and main sources for the study are as follows:

- For the purpose of the energy modelling of the Czech Republic we used data from reports provided by Czech NGOs. These reports include bottom-up studies on the country's different energy sectors (Šafařík / Klusák 2007a, Šafařík / Klusák 2007b and Truxa 2008), scenarios of future final energy demand in those sectors (SEVEn 2008) and the report of the Independent Energy Commission (NEK), headed by Vaclav Pačes, on the future of the Czech Republic's energy system (Pačes 2008). Sources quoted in the commission's report have also been used. An important additional source for figures is the most recent baseline projection for DG TREN (DG TREN 2008).[1] Data provided and used from these sources include:
    - Current structure of primary energy use in Czech Republic, current CO_2 emission levels and structure as well current consumption of electricity, heat and transport fuels.
    - Existing estimates on framework developments such as demographic development and GDP growth up to 2050 and development in transport volumes

[1] For the modelling, data for the starting year (2005) is mainly taken from DG TREN (2008). However, as future energy demand figures until 2050 are based on projections prepared for the report of Czech Independent Energy Commission (SEVEn 2008), some data from the report is also used in the starting year. There are only some minor discrepancies in the data from the two different sources so it has been decided to accept these differences, especially since they are insignificant in respect to the results of the scenarios modelled.

and fuel use by 2050.

- Expectations and study results on the potentials for a restructuring of the Czech energy system such as:
  - Expected trends in energy efficiency and emission intensity.
  - Estimated energy saving potential for industry by 2050 and industry‘s estimated structure.
  - Estimated energy saving potential in residential and tertiary sectors’ buildings incl. cost curves of different measures applied.
  - The estimated potential of renewable energy sources available domestically in Czech Republic.
  - And the estimated potential for decentralization of energy sources (electricity, heat, CHP).

- The assessment of the effects of key energy policies is crucial for the creation of the energy scenarios. For this purpose an expert based approach is employed in order to assess their potential impact on the energy system alone and in combinations of packages of policy measures. Considered policy instruments are e.g.:
  - Financial support and market introduction schemes for renewable energy sources (feed-in tariffs and/or investment support by subsidies or loans).
  - Financial support for investments in energy efficiency and other measures promoting energy efficiency.
  - Changes to the fiscal system to provide a level playing field for sustainable energy solutions and to remove counterproductive subsidies, e.g. by
    - Getting the nuclear power economics fair (abolishing limited liability etc.);
    - Introducing a price on carbon emissions (mainly via the European Emission Trading Scheme (ETS) or Kyoto and post-Kyoto mechanisms) and
    - Introducing an environmental tax reform (increasing fuel or carbon tax, decreasing labour costs).
  - Setting a year by year target for CO_2 and/or GHG emissions (“CO_2/GHG Reduction Act”)
  - Improving the organisation and regulation of the energy sector e.g. by stimulating investments into the electricity grid.

- On the basis of a business as usual scenario derived in accordance with the current study from the European Union (see above) and based on potential data and policy assessments two alternative policy scenarios are modelled. The respective scenario philosophy and the measures taken into account for every scenario are discussed in the respective scenario description. Target values and marginal conditions of the more ambitious alternative scenario are among others: to achieve GHG emissions of 2 tons of CO_2 eq./capita by 2050 with a decreasing trend in the period observed and to build no new nuclear reactors.

- For all three scenarios the following main results are generated:
    - A complete energy balance including an overview of final energy demand by energy carrier and sector, the structure of primary energy supply for electricity and heat production and import dependency.
    - The quantitative results are designed in a way to be comparable to the results of the scenarios prepared by DG TREN (e. g. DG TREN 2008) as well as the official German “Leitstudie” (Nitsch 2008).
    - An overview of CO_2 emissions throughout the modelling period.
- Estimates of the impact of different policy instruments on the above, leading to policy recommendations.

2 Current structure of energy use in the Czech Republic

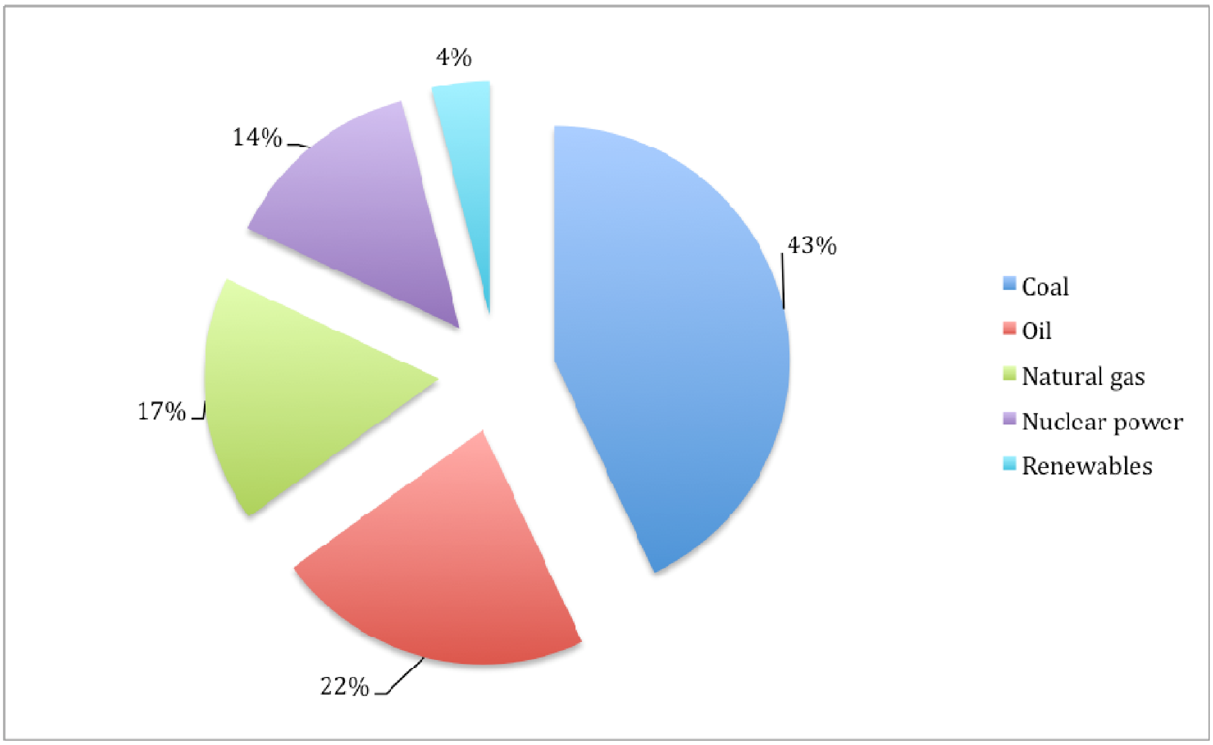
2.1 Overview of the Czech energy supply

In 2005 the Czech total primary energy supply was 1,893 PJ, an increase of 0.5% over 2004. Total primary energy supply (TPES) growth averaged 2.2% per year between 1999 and 2005, while from 1989 to 1999 TPES dropped by 28%. The total TPES decrease between 1989 and 2005 amounted to 9%. This decrease reflects both the dramatic restructuring of the Czech economy during the transition period and the related reduction of energy intensity (IEA 2005a).

Coal is the dominant primary fuel in the Czech Republic. It accounted for 43% of the country's TPES, followed by oil (22%), natural gas (17%), nuclear power (14%) and renewables (biomass (3.1%), hydropower (0.4%)).

The coal share of TPES has decreased from 62.5% to 44.1% since 1989. This drop has been compensated by an increase in natural gas use (whose share of TPES rose from 10.2% in 1989 to 16.7% in 2005) and nuclear power production (rise from 6.5% in 1989 to 14.0% in 2005) (IEA Database).

Figure 1: Primary energy use in Czech Republic by source in 2005



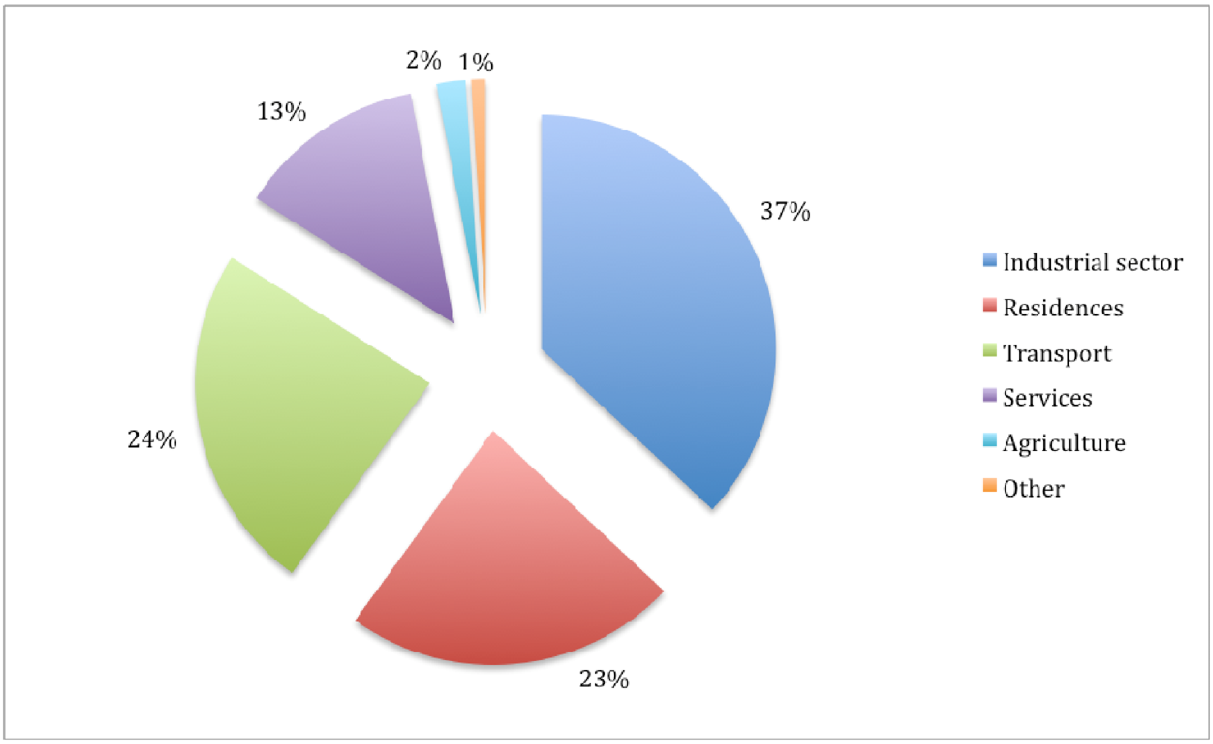
Source: IEA Database.

2.2 Overview of the Czech energy demand

Total Czech final energy consumption amounted to 1,080 PJ in 2005. Final energy demand increased by an average annual rate of 2.3% between 1999 and 2005, while there was a huge drop from 1989 to 1999 by a total of 50.5%. The decrease resulted on the one hand from the drop of economic activity following the transition period and on the other hand from the shift towards less energy-intensive economic activity and increases in energy efficiency across industries and households (IEA 2005a).

The industrial sector is the largest final energy user in the Czech Republic (37.2% in 2005). Residences (23.1%) and transport (23.9%) are the two next biggest sectors. Other sectors, mostly services, account for 15.8%. In the transport sector, road transport is the dominant source for energy demand. Over the long term, the share of road transport rose, while the share of the industrial sector fell. In 1973, industry counted for 55.6% of total final energy consumption, while road transport accounted for just 5.8% (IEA Database).

Figure 2: Final energy consumption of the Czech Republic by sector in 2005



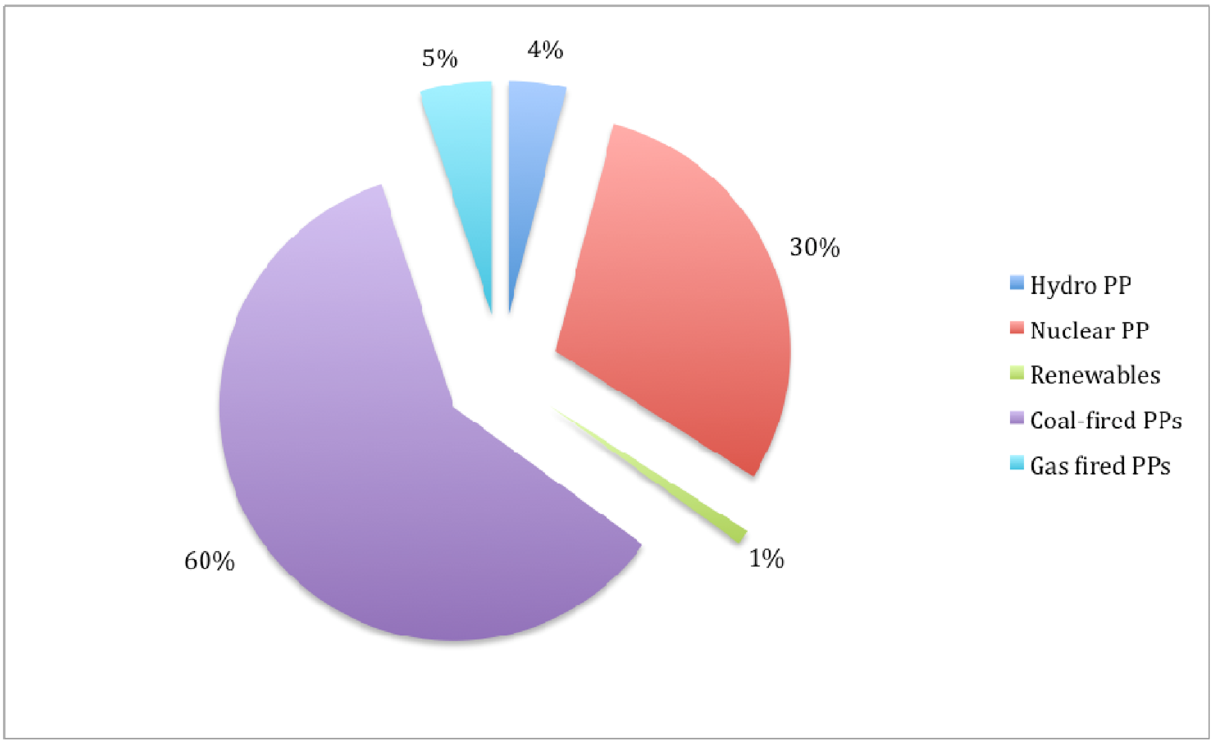
Source: IEA Database.

2.3 Overview of the Czech electricity production and consumption

In 2005 the total gross electricity generation accounted for 82578 GWh in the Czech Republic, while the total Czech final electricity consumption amounted to 55,246 GWh in 2005.

The Czech electricity generation is dominated by coal-fired power plants. In 2005 almost 60% of the electricity was generated in coal-fired power plants. Nuclear power currently is the second most important generating technology, accounting for nearly 30% of gross Czech electricity generation in 2005 (IEA Database).

Figure 3: Czech electricity production by source in 2005



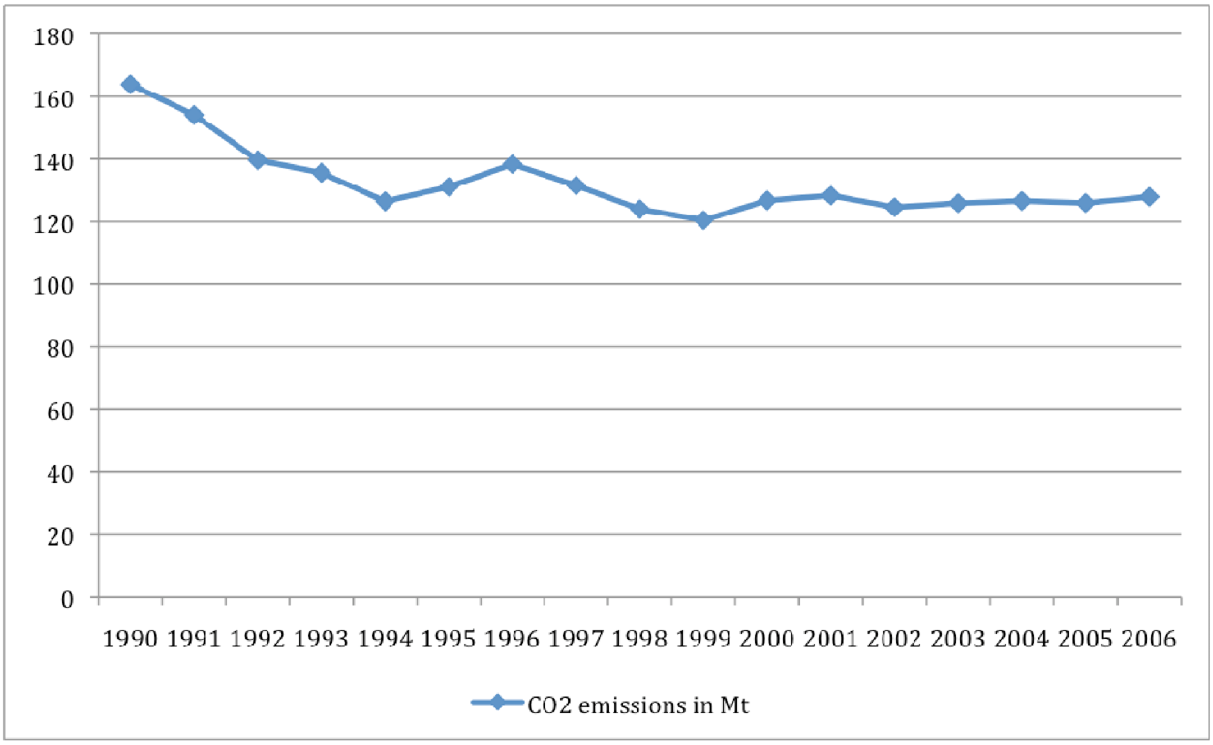
Sources: IEA Database.

The industry sector is the largest electricity consumer, although its demand has been decreasing over the past 20 years. Contrarily, the shares of the residential and commercial sectors have risen considerably.

The Czech Republic is a dominant international trader of electricity in the region. The country has historically been a net exporter. During the 1990s, there was a period when exports decreased substantially due to the refurbishment of coal-fired power plants. In 2005 the country had net exports equivalent to 15% of domestic electricity generation (IEA Database).

2.4 CO_2 emissions of the Czech Republic

Figure 4: Historical development of total CO_2 emissions in the Czech Republic (CO_2 emissions in Millions of Tons)



Source: Eurostat Database.

CO_2 emissions from energy consumption and use account for around 85 – 90% of the Czech Republic's GHG emissions. This is a comparatively high percentage, which results from the country's relatively high energy intensity and its small agricultural sector (agriculture is a major source for GHGs other than CO_2). The Czech Republic's total CO_2 emissions were nearly 126 Mt in 2005, equivalent to a 22% reduction from 1990 levels.

Under the Kyoto Protocol, the Czech Republic must reduce its total GHG emissions by 8% from 1990 levels in the period 2008 – 2012. This target has already been achieved due to the massive drop in emissions during the transition period of the 1990s.

In order to prevent the worst consequences of climate change it is required to reach or at least come close to the maximum of 2 tons of greenhouse gas emissions per capita in 2050. The per capita greenhouse gas emissions amounted to 12 tons in 2005 in the Czech Republic (IEA 2005a; Eurostat Database).

2.5 Current energy policy in the Czech Republic

2.5.1 Energy strategy of the Czech Republic

The State Energy Policy (2004) document was formulated by the Ministry of Industry and Trade and it was approved as a government decision in 2004. The policy defines the basic priorities of the long-term development of the Czech energy sector:

- Independence
    - Independence from foreign energy sources
    - Independence from energy sources from risky regions
- Safety
    - Safety of energy sources including nuclear safety
    - Reliability of supplies of all kinds of energy
    - Reasonable decentralization of all energy systems
- Sustainable development
    - Environmental protection
    - Economic and social development

The state energy policy goals are directed to fulfil the basic priorities in a more specific form. Four main goals have been defined:

1. *Maximising energy efficiency* is the primary goal of SEO. The Czech government regards increasing energy efficiency as the most important measure to achieve the priorities of independence and safety as well as sustainable development.
2. Ensuring the effective amount and structure of primary energy sources consumption in order to fulfil the *priorities of independence, safety and sustainable development* within a sufficiently diversified and permanently stable structure of primary energy sources and electricity generation. This objective includes the promotion of electricity and heat produced from renewable energy sources, focuses on the maximum independence from foreign energy sources and aims at optimizing the share of nuclear energy within a long-term energy mix respecting the essential operational safety requirements. As coal and nuclear energy are regarded as domestic energy source the current energy policy supports them as priority.
3. *Maximising environmental friendliness* is goal number three of the Czech SEP. This will be based on an efficient structure of energy consumption and environmentally sound methods of electricity and heat generation.
4. The last priority of SEP is completing the *transformation and liberalization* of the Czech energy sector introducing the market model of the energy sector in line with the EU directives.

2.5.2 Energy Efficiency Policy Measures in the Czech Republic

The first Czech Energy Efficiency Action Plan was disclosed in 2008 in compliance with the European Directive on energy end-use efficiency and energy services (2003/32/EC). The aim of the Action Plan is to reduce the annual consumption of the period 2002 to 2006 by 9% in the period of 2008 to 2016. The Czech national energy saving target for 2010 is to reach the level of 3 573 GWh, which is 1.6% of the average energy consumption (Energy Efficiency Action Plan 2008).

Since December 2007 the agency Czechinvest is responsible for preparation, realization and consistent evaluation of the Operational Program Industry and Enterprise 2004 – 2006 „subprogram Energy savings and RES“ and the Operational Program Enterprise and Innovation 2007 – 2013 „subprogram Eco-Energy“. The State Environmental Fund operates the Operational Program Infrastructure 2004 – 2006 and the Operational Program Environment 2007 – 2013. The Ministry of Industry and Trade and the Ministry of Environment are responsible for the preparation, realization and consistent evaluation of the Government Program for the Support of Energy Savings and RES. The Operational Program Environment supports renewable electricity, heat and energy saving projects in the period 2007 – 2013 by overall sum 673 million EUR (ODYSSEE 2008).

Czechinvest operates the key energy efficiency programs in the industrial sector. These support small and medium enterprises and are financed from ERDF. The Government Program part A, which is operated by the Ministry of Industry and Trade, includes investment subsidies for energy efficiency improvement in energy production and distribution facilities, combined heat and power production and reduction of energy demand in industrial enterprises and small and medium enterprises (ODYSSEE 2008).

The Energy Management Act (No. 406/2000 Coll.) was amended by Act No. 177/2006 Coll. in 2006. This amendment implemented the EU Directive 2002/91/EC on the „Energy Performance in Buildings“ into the Czech Legal Framework.

The key energy efficiency programmes in the area of household and services are operated by the State Environmental Fund and financed from ERDF. Further energy efficiency programs of the Ministry of Industry and trade include measures for improving energy efficiency in buildings. These measures include the replacement of windows, heat regulation and thermal insulation improvement (ODYSSEE 2008).

The State Environmental Fund started to operate a large (1 billion Euros) program to support energy efficiency measures in households. This program was announced in April 2009 and will be financed through Green Investment Scheme under the Kyoto Protocol.

2.5.3 Renewable energy policy in the Czech Republic

2.5.3.1 Renewable energy targets of the Czech Republic

The European Directive on the Promotion of Electricity from Renewable Energy Sources in the Internal Electricity Market from 2001 (2001/77/EC) requires an 8% share of renewable energy sources on Czech gross electricity consumption by 2010.

The Indicative Target set by the European Biofuels Directive from 2003 requires the Czech Republic to adopt a biofuel consumption of 5.75% of petrol and diesel use for transport in 2010.

In 2004, the Czech parliament approved the national energy strategy setting targets for 2030 (IEA 2005a; EREC 2008). Concerning renewable energy sources, these targets are the following:

- the share of renewable energy sources in electricity production should be 16 – 17% in 2030, and

- the share of renewable energy sources in the primary energy supply should be 6% in 2010 and 15 – 16% in 2030.

The new Renewable Energy Framework Directive[2] from 2009 sets further mandatory targets for the Czech Republic:

- renewable energy sources will account for 13% of the final energy consumption in 2020
- biofuels will account for at least 10% of the final energy consumption in transport in 2020.

2.5.3.2 Czech policy support instruments for electricity from renewable energy sources

Implementing the EU Directive 2001/77/EC in Czech legislation, Act No 180/2005 on the promotion of electricity produced from renewable energy sources, entered into effect on 1 August 2005. Its key features are:

- Preferential connection to the grid. There is an obligation for operators of the regional grid systems and the transmission system operator to purchase all electricity from renewable sources
- The guarantee of revenue per unit of electricity produced over a 15-year period as of the date a plant is put into operation
- The possibility of choosing between two support systems between minimum feed-in tariffs or green bonuses. In the case of minimum feed-in tariffs all the electricity produced can be sold to the relevant distribution system operator. Green bonus means electricity produced from renewable sources can be sold on the single electricity market and the producer receives surcharges on electricity market prices.
- The support of electricity used for internal consumption (not supplied to the grid)

A feed-in system for electricity from renewable energy sources and for combined heat and power production was implemented in 2002. The Renewable Energy Sources Act was adopted in 2005, in order to extend this system by offering a choice between a feed-in tariff for a guaranteed price or a green bonus, which is paid on top of the current electricity market price.

In case of the fixed price, the operator of the distribution system is obliged to purchase the electricity for regulated fixed prices. The price is valorised through a price index of the industrial producers. The feed-in tariffs are fixed each year for one year ahead for each type of RES.

In case of the Green Bonus, the producer sells electricity on the market for the wholesale price. Additionally, he receives a premium (=Green Bonus) (in CZK/MWh) from the distribution system operator. Green Bonuses are fixed each year for one year ahead for individual types of RES in such a way that the total of revenues for the average purchase price is

2 Directive on the promotion of the use of energy from renewable sources amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

expectedly higher than that for the fixed purchase prices. The price of the Bonus is flexible according to the purchase price of the electricity. For electricity from combined combustion of biomass and fossil fuels, only the Green Bonus can be applied.

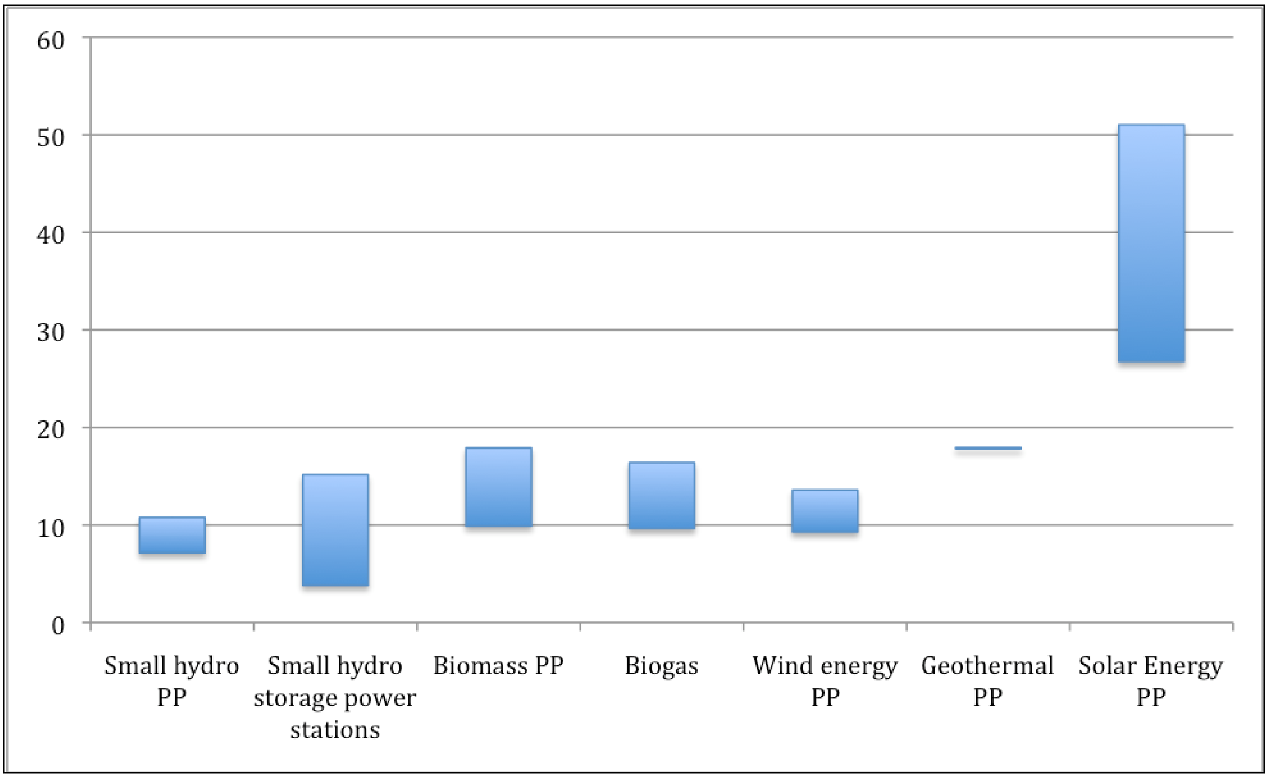
The prices may not be lower than 95% of the value of the year before. Prices are set on the following assumptions:

- Return on investment of 15 years
- Prices are differentiated according to the renewable energy source
- Prices are differentiated by the year of commissioning

Figure 5a gives an overview on the diversity of the current feed-in tariffs for various renewable electricity technologies. The older is the renewable power plant the lower is the tariff paid for the produced electricity within one energy source. Different technologies receive different feed-in tariffs. Figure 5b shows the current Czech green bonuses similar to Figure 5a.

Figures 5a, b: Czech Feed-in tariffs [a] and Green Bonuses [b] for different renewable technologies in € Cent/kWh[3], 2009[4]

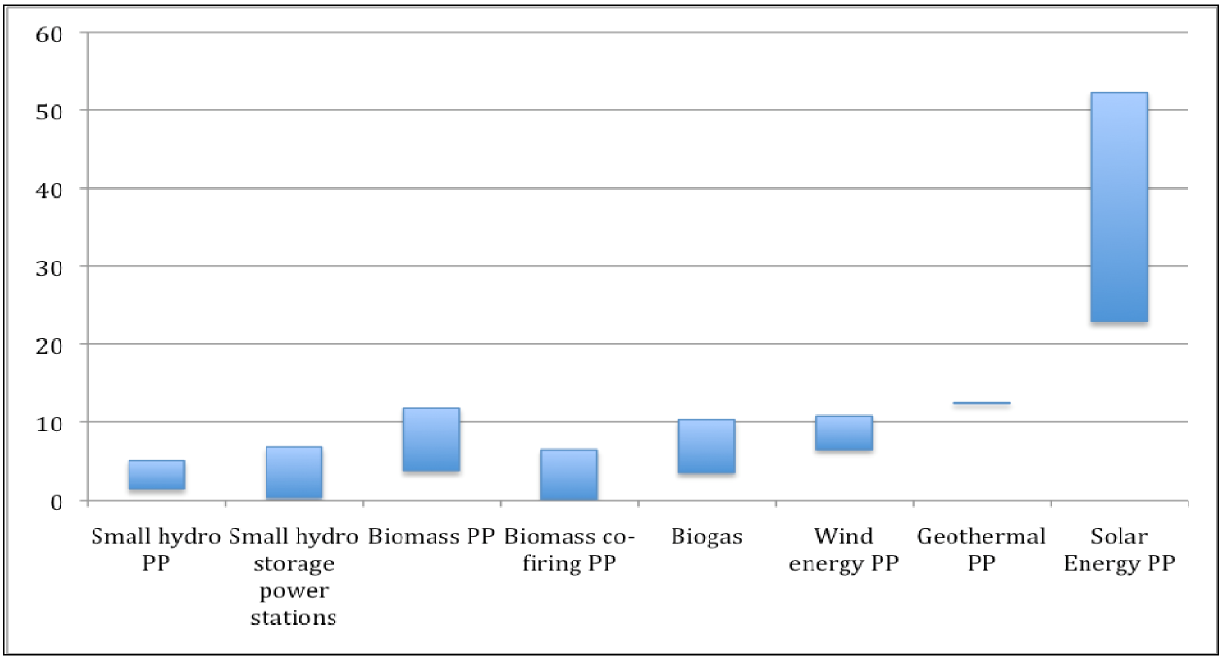
a



[3] 1 CZK = 0,03989 EUR

[4] The Energy Regulatory Office's Price Decision No. 8/2008 of 18 November 2008.

b



Source: Based on data from the Czech Energy Regulatory Office's Price Decision.

Beside of the Feed-in tariff and Green bonus system there is a State program for energy saving and the use of renewable energy sources offered by the Ministry of Industry and Trade (subsidies from Part A) and by the Ministry of Environment (subsidies from Part B). Subsidies from Part A of the program may amount to a maximum of 30% of capital costs, but no more than CZK 2.8 million, while subsidies from Part B of the program may amount to a maximum of 90% of the calculation basis for the aid in the case of local government units (municipalities) and non-profit organizations. Subsidies under Part B of the State Program may amount to 40% of the capital costs in the case of businesses.

Furthermore the Czech Republic offers tax exemptions and reduced interest rates for renewable electricity investors. New renewable electricity plants are exempted from income taxes in the first five years after commission. Reduced interest rates are offered for renewable electricity plant operators. The subsidies may account for a maximum of 46% of capital costs, but no more than CZK 30 million. Non-business entities can receive credits up to 35% of the costs, while business entities can obtain credits equivalent to 90% of general costs at an interest rate of 4% per annum over a 12-year period (EREC 2008; Pál et al 2006).

2.5.3.3 Support for heat production from renewable sources

There is no targeted support for renewable heat production in the Czech legislation, however renewable heat presents most of domestic renewable energy potential. These projects gain mainly financial contribution from EU funds.

The Operational Programme for 2004-2006 includes the subsidy scheme "Exploitation of Renewable Energy Sources", intended for non-business legal persons. The scheme focuses on the construction of plants using biomass, on transforming current systems into systems using RES and on the use of RES-heat from municipal boiler houses. The Operational

Programme Environment 2007 – 2013 supports renewable heat together with renewable electricity and energy saving projects by overall sum 673 million Euro.

Subsidies from the European Regional Development Fund may amount to a maximum of 75% of the basis for the calculation of aid (eligible costs), but no more than the equivalent of EUR 10 million.

In addition, a project can be co-financed from the State Environmental Fund up to a total amount of 90%. The Fund's resources may be used to obtain a subsidy for project documentation of up to 50% of eligible costs; this may be a maximum of 3% of the basis for the calculation of investment aid, but no more than CZK 3 million (EREC 2008).

2.5.3.4 Support for biofuels

Addition of biomaterial is obligatory for producers, distributors, and importers. The Government Resolution No. 1080 of 2006 provides a minimum quantity of biofuels in the range of motor-vehicle fuels without any subsidies or support from the state. On the basis of this resolution, amendments were made to the Act No 86/2002 Coll. on clean air protection. The amendment concerns the setting of a minimum amount of biofuels. Any person bringing motor-vehicle petrol or diesel fuels into free tax circulation in the Czech Republic must ensure that they contain at least a minimum proportion of biofuels. The amendment introduces the following minimum values of biofuels blended with fuel:

- as of 1 January 2008, 2% of the total amount of motor-vehicle petrol fuel;
- as of 1 January 2009, 3.5% of the total amount of motor-vehicle petrol fuel;
- as of 1 January 2009, 4% of the total amount of motor-vehicle diesel fuel (EREC 2008).

2.5.3.5 Promoting energy crops in agriculture

The objective of the program "Promoting the cultivation of crops for energy use in 2007" is to promote the establishment and maintenance of standing crops for energy use with aid of CZK 3,000 per hectare. In this program, stated energy crops must be grown specifically for energy use.

Aid for the cultivation of energy crops is provided, the conditions are governed by Governmental Order No 80 of 11 April 2007 which lays down certain conditions for the provision of a payment for the cultivation of energy crops (EREC 2008).

3 Overview of scenario results

3.1 The Wuppertal Scenario Modelling System (WSMS)

In order to optimally achieve the targets of the study as mentioned above we use the Wuppertal Scenario Modelling System (WSMS), which has been developed over more than a decade and has been frequently used and updated in several research projects:

- These include the first and still most relevant scenario studies of the German energy system by 2050 on behalf of the German Parliament's Enquete Commission "Sustainable energy Supply" and on behalf of the German Environmental Protection Agency. Based on these the Federal Ministry of the Environment now publishes an updated scenario by 2050 annually ("Leitstudie", see Nitsch 2008).
- The model has been employed also for own scenario analyses on the European level where three influential EU-wide scenario analyses have been published on behalf of the WWF ("Target 2020", published in 2005 and updated in 2008) and the European Parliament ("Security of Energy Supply", published in 2006). These scenarios have been among the first works to analyze strategies to achieve a 30% GHG emission reduction for the EU by 2020.
- Furthermore the model has been used in detailed analysis for specific sectors in scenario and potential studies for the EU. The Wuppertal Institute is member of the long-range energy modelling consortium lead by NTUA Athens, which provides scenario analyses for the DG TREN. We also participate in a larger study on potentials for energy efficiency in the EU lead by Fraunhofer ISI.
- Several other applications of the Wuppertal Scenario Modelling System include scenario analysis for several German regions and cities, for nations such as Germany and Iran as well as on a worldwide level.

For the quantification and combination of potentials, strategies, policies and measures, and the calculation of scenarios we use the Wuppertal Scenario Modelling System.

- This system uses a technology-oriented, sectoral, bottom-up approach. Corresponding to its relevance for GHG-emissions, the energy sector is modelled with the greatest detail using appliance or end-use specific sub-models for every demand sector (households, tertiary, industry, transport) and a purpose-oriented model of the transformation sector[5]. GHG emissions in the energy sector are calculated based on the final and the primary energy balance.
- The system applies a heuristic (i.e. expert-based) approach in order to formulate potentials and strategies and in order to estimate market penetration rates of new technologies, market shares of fuels etc[6]. The model as such does not carry out a math-

5 A description of model detail and philosophy as applied for Germany is given in Fischedick et al (2002).

6 The expert-based approach is described in detail in Lechtenböhmer/Thomas (2004). For the calculations in this study a simplified version has been employed.

ematical optimisation of strategies, as the results of those mathematical optimizations are often quite limited in their usability and tend to be very much driven by methodological decisions. Furthermore in optimization models decisions are internalized into the model and sometimes become intransparent. Instead the WSMS employs a simulation approach taking economic calculations, assumed preferences and foresight of decision makers and other criteria explicitly into account for the definition of the future energy system. This of course does not reveal the theoretical least cost system but instead offers more transparency and a more direct formulation of scenario strategies.

Through implementing selected and – if necessary – modified/extrapolated sectoral strategies in an integrated scenario calculation framework, overlaps (with regard to double counting of emission reductions resulting from energy savings in the demand and supply sectors) are removed and synergies accounted for.

3.2 No Active Policy scenario

3.2.1 Major assumptions

The first scenario described in this report, the *No Active Policy* scenario, is a reference scenario of the Czech Republic's energy system. As the title of the scenario suggests, we assume for this scenario that no new energy policies aiming to bring about structural changes to the country's energy system will be enacted throughout the observed period (i.e. until 2050). While this is neither realistic nor desirable, the *No Active Policy* scenario was developed to show what would happen if the current energy market framework were not to change. As in other scenario studies, such a reference scenario aims to highlight the problems resulting from a business-as-usual development. These problems are then addressed in the alternative scenarios, which assume appropriate policy changes.

While it is difficult to define a business-as-usual development of an energy system, especially looking more than four decades into the future, we've made the following major assumptions for developing the *No Active Policy* scenario:

- Assumptions regarding economic growth as well as population development are taken from the Independent Energy Commission's report (Pačes 2008). These assumptions are identical in all three scenarios of this report and they are provided in the tables in chapter 3.6.
- As of now there are no permissions for the development of new coal mines in areas in the Czech Republic that are not currently in use. We therefore assume that domestic coal production will be limited to the coal mining areas already under use.[7]
- The past decades have shown that investors are reluctant to invest in new nuclear

[7] This assumption has of course also been made in the two alternative scenarios. In those two scenarios however, coal demand is reduced to such an extent that domestic demand can be met by existing coal mines anyway.

power plants without government support in the way of guaranteed electricity prices or cheap long-term loans. As we assume that no such government support is provided, no new nuclear power plants are assumed to be built in the future.

3.2.2 Final energy demand

Assumptions regarding the future development of final energy demand in the Czech Republic in the *No Active Policy* scenario are based on the reference scenario (*Scenario C*) of the report of the Czech Independent Energy Commission (Pačes 2008, SEVEn 2008).[8] Figure 6 compares these assumptions for total final energy demand with reference assumptions from two other scenario studies (DG TREN 2008, IEA 2005a) released in recent years.[9] All three scenarios assume that final energy demand will rise in the coming decades from about 1.100 PJ in the year 2005 to up to 1.400 PJ in the year 2030. In 2030 *Scenario C* assumes a total final energy demand of 1.274 PJ, rising to 1.297 PJ in the year 2040 and remaining virtually flat in the following ten years. This is equivalent to a 19% rise between 2005 and 2050.

Final energy demand in the *No Active Policy* scenario (based on *Scenario C* of the Independent Energy Commission's report) increases strongly until 2020 as high economic growth is assumed. Average annual economic growth rates for each five year period between 2005 and 2020 are between 3.6 and 5.1%.[10] Between 2020 and 2050 annual economic growth rates are assumed to decline steadily from 3.2 to 1.9%. The relatively slow economic growth in the latter half of the observed period can be partly explained by the expected decline in population (from 10.3 million in 2020 to 9.4 million in 2050). Due to the slowing of economic growth, its effect on increasing energy demand is more and more offset by an increasingly less energy intensive economic structure as well as by moderate improvements in efficiency.

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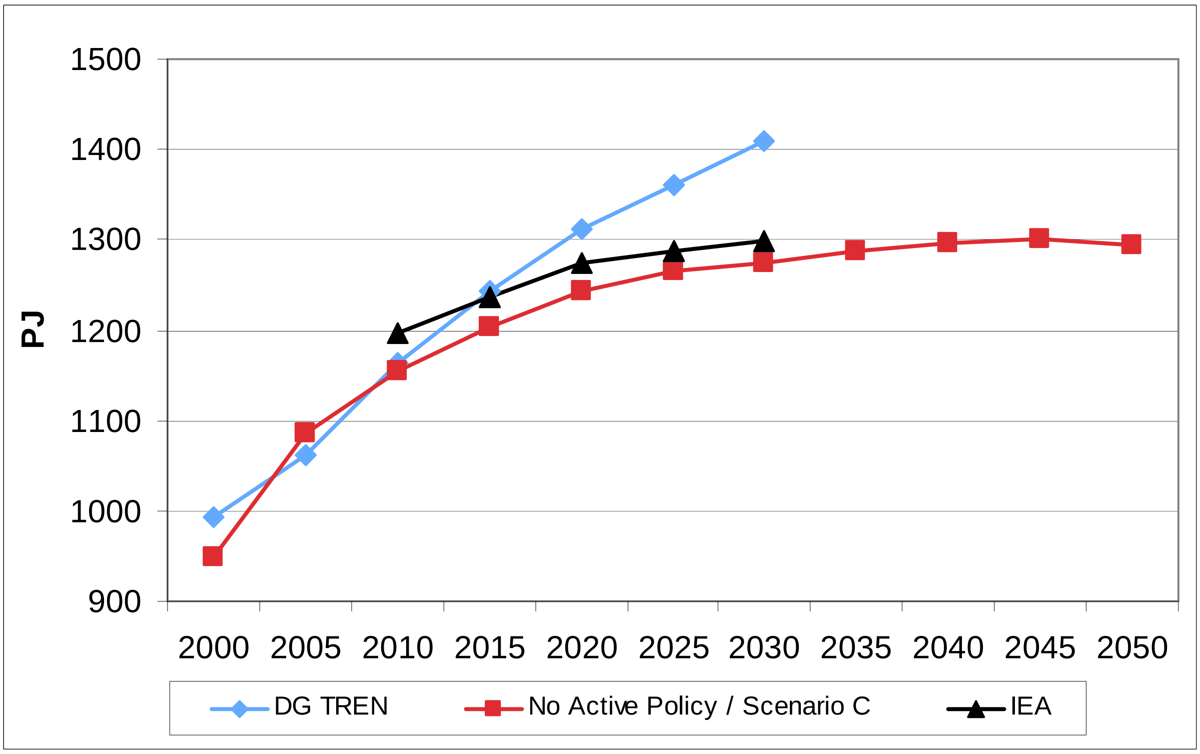
[8] While we take final energy demand data from the report of the Independent Energy Commission, all data concerning energy supply are modelled independently from the commission's data on energy supply.

[9] Note that the scenarios of the other studies provide data only until 2030.

[10] The current global economic downturn and its likely effects on economic growth rates in the Czech Republic are not accounted for in these figures. For the sake of consistency and due to difficulties in assessing the future consequences of the current economic developments, we have chosen not to alter the economic assumptions of the Independent Energy Commission's report.

Figure 6: Comparison of total final energy demand in different reference scenarios (in PJ)



Sources: DG TREN 2008, SEVEn 2008, IEA 2005a.

Figures 7a-d show the development of final energy demand in the various sectors (tertiary, industry, transport and household) for both the data from the Independent Energy Commission (Pačes 2008, SEVEn 2008) used as basis for the *No Active Policy* scenario and from a recent study by the EU (DG TREN 2008).[11] IEA (2005a) does not provide sector specific data on final energy demand. While there's general agreement between the two data sources regarding the trend of final energy demand in the industry and transport sectors, assumptions about the future development of final energy demand in the tertiary and household sectors differ more significantly. The EU study assumes higher future final energy demand compared to the Independent Energy Commission (*Scenario C*) in all sectors except for in the industry sector.

In the tertiary sector final energy demand in the *No Active Policy* scenario is expected to decline slightly over the course of the observed period. This is true despite economic growth in this sector and is explained by moderate efficiency gains in heating, hot water and electrical appliances.

For the household sector, *scenario C* expects final energy demand to decline after 2015. Similar to the tertiary sector, the main energy savings are expected to come from better insulation of existing and new buildings. This leads to a reduction of energy demand for heating from around 185 kWh/m^2 per year at present to 117 kWh/m^2 per year by 2050. Despite a growth in electric appliances, their total energy demand is expected to decline slightly over the whole period (while rising at the beginning of the period) as their efficiency improves. Energy demand for both cooking and warm water is also expected to fall.

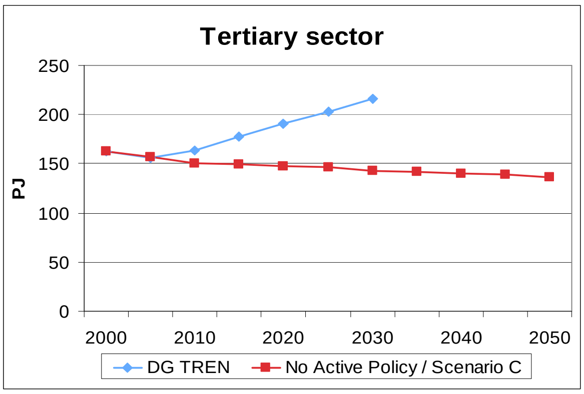
[11] The exact break-up of individual sectors may differ between the two sources.

Scenario C assumes average annual energy intensity reductions in industry of 1.5% as a consequence of technological improvements and structural changes. However, these relative reductions are not sufficient to compensate for the increase of industrial energy consumption resulting from GDP growth. Final energy demand in this sector rises from 436 PJ in 2005 to 534 PJ in 2050.

Scenario C expects a significant increase in demand for transportation, mainly as a result of economic growth. Individual passenger road transportation (in person kilometres) is expected to double by 2050 compared to 2005 while freight road transportation (in ton kilometres) and both forms of rail transportation (person and fright) are expected to more than double in that span. Only gradual technological improvements are assumed that are unable to noticeably curb the increase in final energy demand caused by the additional demand for transportation. A moderate increase in the share of hybrid cars and biofuel-powered cars is assumed in the *No Active Policy* scenario.[12]

Figures 7a-d: Comparison of final energy demand in the various sectors in different reference scenarios (in PJ)

a



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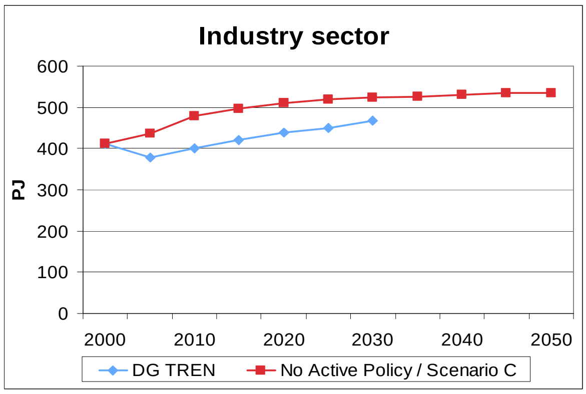

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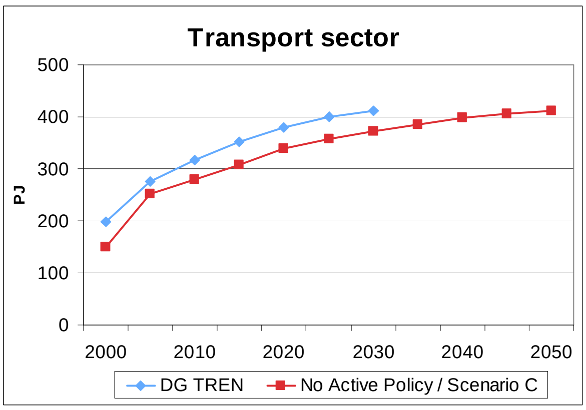

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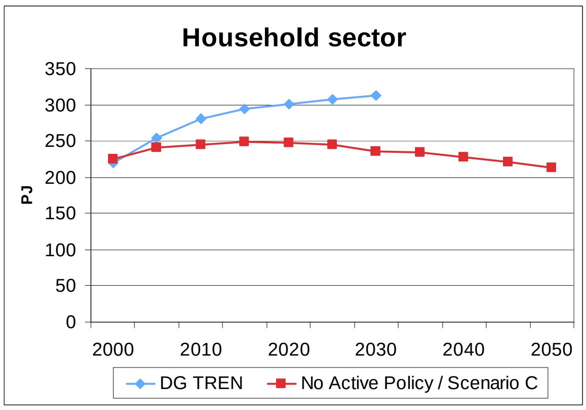


Sources: DG TREN 2008, SEVEn 2008.

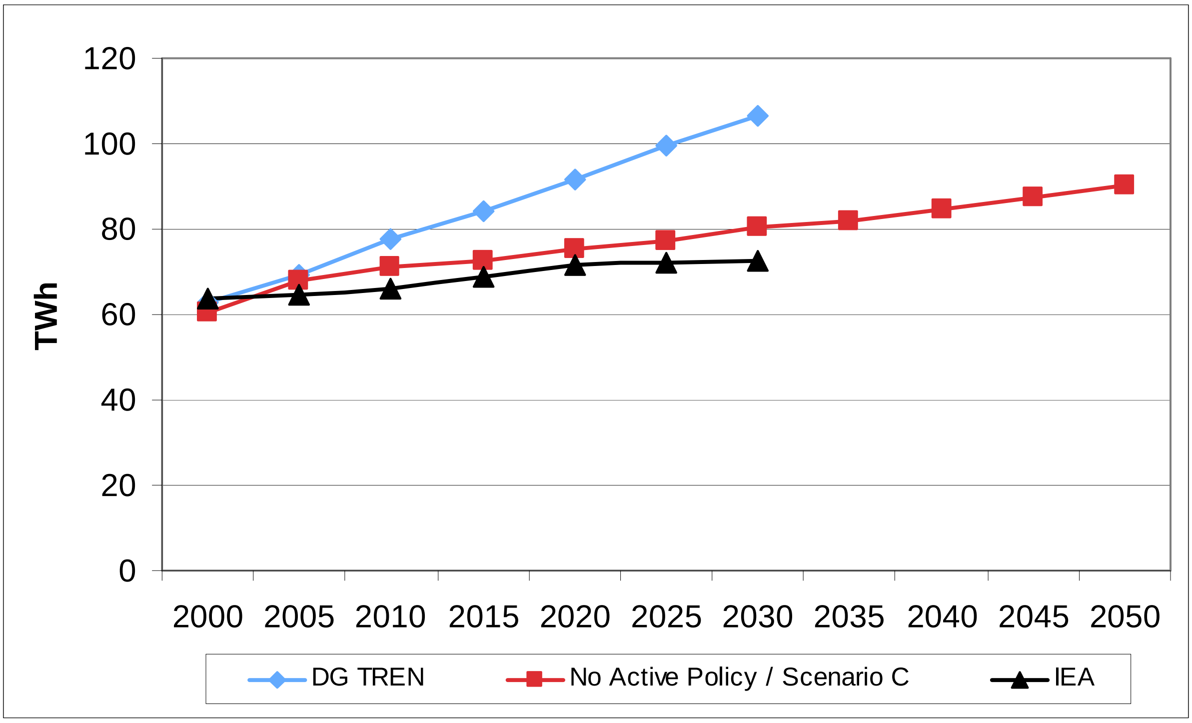
12 Regarding the share of energy sources in transportation we have chosen for the No Active Policy scenario to deviate from the Independent Energy Commission's *Scenario C* assumptions. This mainly concerns the assumptions regarding the use of gaseous fuels, which in *Scenario C* increases from less than 3% in 2005 to more than 20% in 2050. We do not see a reason to expect such a strong growth in the share of gaseous fuels in a reference scenario and thus made own assumptions about the energy mix in transportation. In the

3.2.3 Electricity consumption and electricity generation

3.2.3.1 Electricity consumption

Gross electricity consumption is expected to increase considerably over the coming decades (see Figure 8). Based on the data from *Scenario C* of the Independent Energy Commission, we assume a steady rise from 67.8 TWh in 2005 to 90.5 TWh in 2050 in the *No Active Policy* scenario, corresponding to an increase of 33% over the 45-year period. This increase is more pronounced than both the expected increase in total final energy demand (see above) and the expected rise in primary energy supply (see below) over the same period. The already mentioned European scenario study (DG TREN 2008) assumes an even higher increase in electricity consumption until 2030, rising to 106.7 TWh by that year, corresponding to a 70% increase over the 25 year period. In contrast, the IEA scenario released in 2005 expects electricity consumption to increase much slower, to only 72.3 TWh.

Figure 8: Comparison of gross electricity consumption in different reference scenarios (in TWh)



Sources: DG TREN 2008, SEVEn 2008, IEA 2005a.

While the dissemination of more efficient electric appliances helps to keep electricity demand stable in the household sector and even reduces demand in the tertiary sector, electricity demand in the industry sector (+51% in 2050 compared to 2005) and especially in the transport sector (+510%) increases markedly in the *No Active Policy* scenario. The use of more efficient technology in the industry sector cannot compensate for the additional electricity demand resulting from the expected significant growth of the industrial sector. In the transport sector the increase not only stems from a general increase in transportation (in-

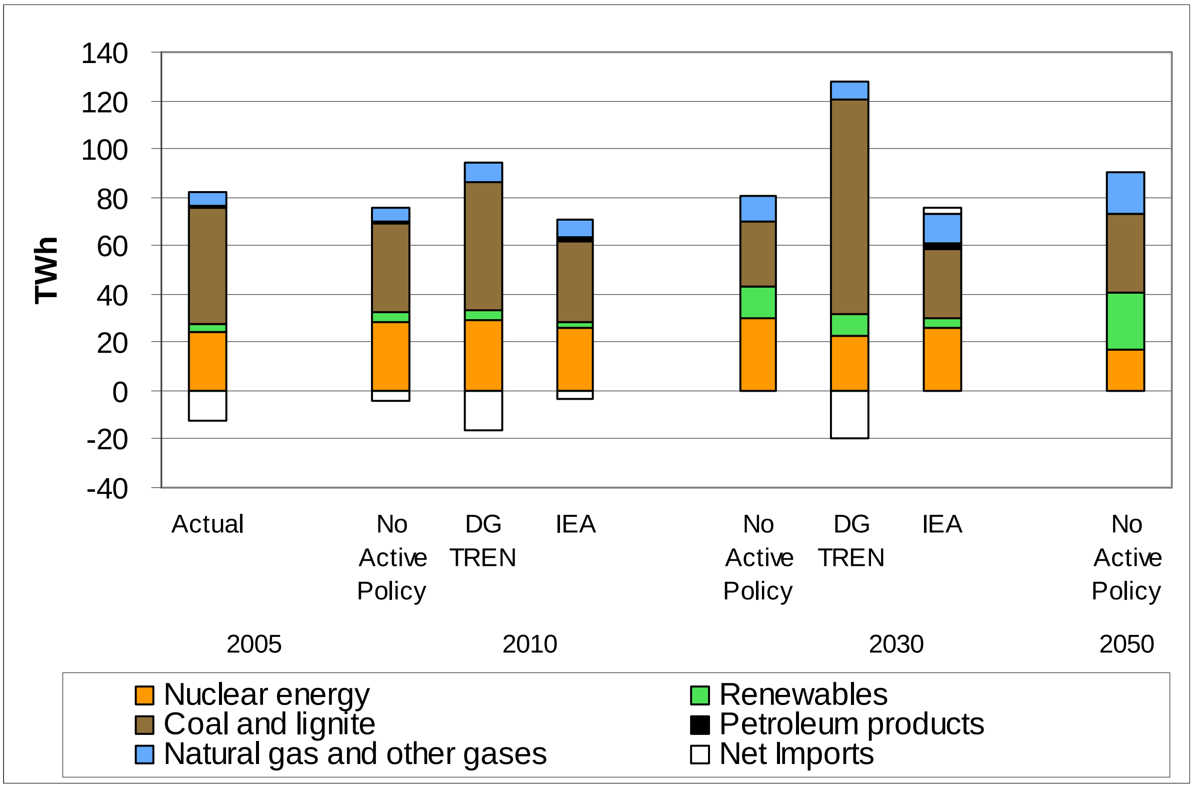
No Active Policy scenario gaseous fuels in 2050 provide 5% of final energy demand, while biofuels provide 16% and electricity 10%. The rest (almost 70%) is still provided by petrol and diesel.

cluding railway transportation), but also from an increasing share of electricity in the sector's final energy demand. The share rises from 3% in 2005 to 10% in 2050 as more electric passenger cars (both hybrid and full-electric) are used and an increasing part of the railway infrastructure is electrified.

3.2.3.2 Electricity production

Figure 9 shows gross electricity production in 2005, projected electricity production in the *No Active Policy* scenario for the years 2010, 2030 and 2050 and projected electricity production of two other reference case scenarios for the years 2010 and 2030. It is notable that in 2030 electricity generation in the DG TREN (2008) scenario is much higher than in both the *No Active Policy* scenario and the IEA (2005) scenario. This is due to the much higher electricity demand (see Figure 8) and also due to the considerable share (16%) of gross electricity production expected to be exported in the DG TREN scenario in 2030 (see Figure 9).

Figure 9: Comparison of gross electricity production and net electricity imports in different reference scenarios (in TWh)

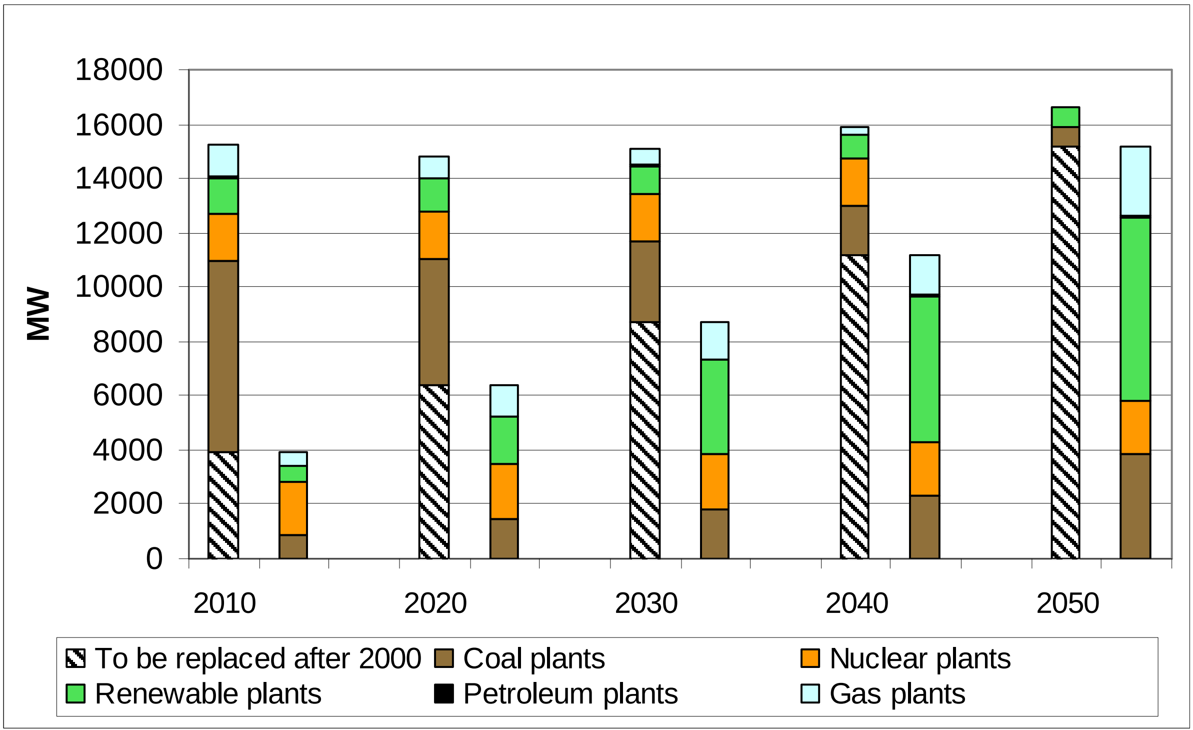


Sources: DG TREN 2008, IEA 2005a, own calculations.

In the *No Active Policy* scenario the increasing demand for electricity is largely met by

- the elimination of net electricity exports by the year 2020
- the increasing use of renewable sources to generate electricity, especially biomass and solar energy and
- the addition of considerable new capacity of both new coal and new natural gas power plants (1,000 MW each) at around 2045 to help compensate for the planned decommissioning of nuclear power plant Dukovany (see Figure 10).

Figure 10: Power plant capacity in the *No Active Policy* scenario (in MW, including CHP) with separate depiction of capacity added after the year 2000



Source: Own calculations.

The elimination of electricity exports and the increased contribution from renewable energy sources and natural gas not only help to meet the increase in electricity demand but also compensate for the decreased contribution of coal to total electricity generation. As current coal plants are retired and existing coal mines are depleted, this contribution decreases steadily from 44.1 TWh in 2005 to 25.6 TWh in 2040. In order to help compensate for the planned decommissioning of nuclear power plant Dukovany in 2045, electricity generation from coal power plants rises again after 2040 to 33 TWh in 2050 as total coal power plant capacity (including CHP) increases between 2040 and 2050 after having decreased steadily between 2005 and 2040 (see Figure 11).

Table 1 shows the average efficiencies of electricity production of newly-built and of all existing non-CHP power plants as well as average efficiencies of electricity and heat production of newly-built and of all existing CHP power plants. We assume that in the *No Active Policy* scenario all kinds of newly-built thermal power plants will show moderate increases in efficiency over time. By the middle of the century, new coal plants will have thermal efficiencies of almost 50%, while gas-powered plants achieve efficiencies of 60% and biomass plants efficiencies of 38%. Similarly, moderate improvements are also assumed for newly-built CHP power plants. Average efficiencies of all existing plants remain below those of newly-built plants at all time, as existing plants include older and less efficient ones.

Table 1: Average efficiencies of electricity (and heat) production in different types of non-CHP and CHP power plants in the *No Active Policy* scenario

Newly-built non-CHP plants

	2005-2010	2015-2020	2025-2030	2035-2040	2045-2050
coal	43%	45%	46%	47%	49%
gas	52%	54%	56%	58%	60%
biomass	30%	32%	34%	36%	38%

All existing non-CHP plants

	2010	2020	2030	2040	2050
coal	35%	37%	38%	40%	44%
gas	34%	53%	53%	53%	55%
biomass	29%	32%	33%	34%	34%

Newly-built CHP plants

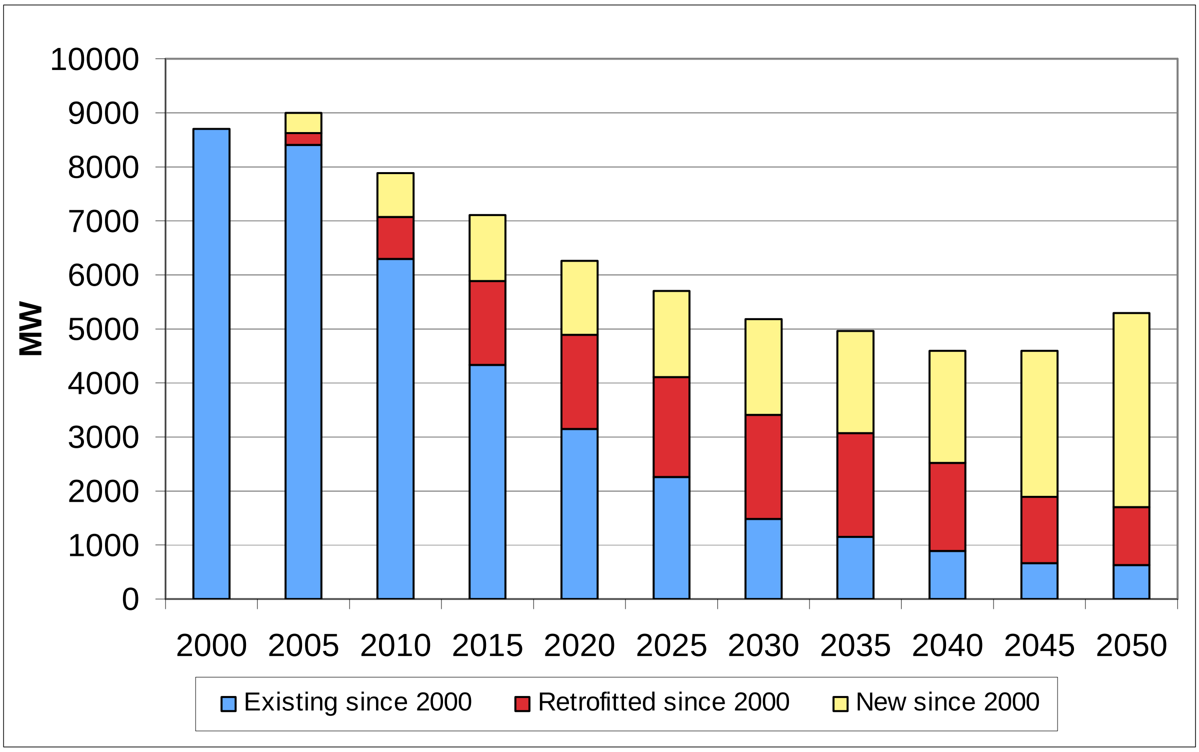
	2005-2010	2015-2020	2025-2030	2035-2040	2045-2050
coal	74%	76%	77%	78%	80%
gas	82%	83%	85%	87%	89%
biomass	79%	80%	81%	82%	83%

All existing CHP plants

	2010	2020	2030	2040	2050
coal	69%	70%	71%	72%	73%
gas	80%	81%	81%	82%	82%
biomass	72%	76%	78%	79%	79%

Sources: IEA 2008a, own calculations.

Figure 11: Structure of coal power plant capacity (in MW, including CHP)



Source: Own calculations.

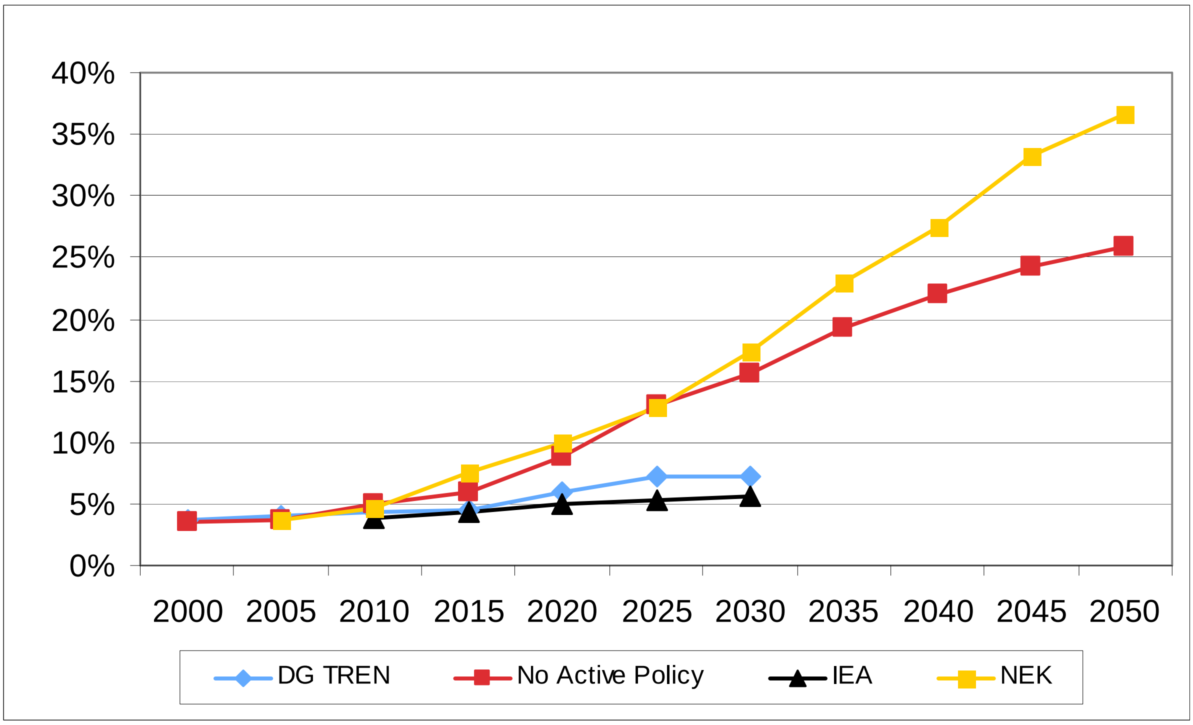
In the *No Active Policy* scenario coal continues to be the number one energy source for electricity generation in the Czech Republic, although its share falls from 55% in 2005 to 36% in 2050. Net imports of coal are needed from 2015 on in order to keep the share from falling further. By the year 2050 388 PJ of coal are imported.

We expect electricity from renewable energy sources to become increasingly competitive compared to electricity from conventional energy sources during the course of the coming decades. This is true even under the assumptions of the *No Active Policy* scenario, which does not expect any further political support measures for renewable energy use. The increase in competitiveness is a result of two relatively robust assumptions about the future:

- Prices of fossil and nuclear fuels will rise over the coming decades and
- Costs of renewable energy technology will continue to decline quickly.

Figure 12 shows that the share of renewable energy in electricity generation rises relatively steadily in the *No Active Policy* scenario from 4% in 2005 to 26% in 2050. The figure also shows that the share increases faster than in the two reference scenarios by IEA and DG TREN, where renewable energy contributes only about 6% and 7% respectively in the year 2030 (compared to 16% in the *No Active Policy* scenario). On the other hand, the reference scenario of the Independent Energy Commission (NEK) assumes higher growth of the share of renewable energy in electricity generation than our *No Active Policy* scenario does, especially after 2025.

Figure 12: Comparison of renewable energy share in electricity generation in different reference scenarios (in %)

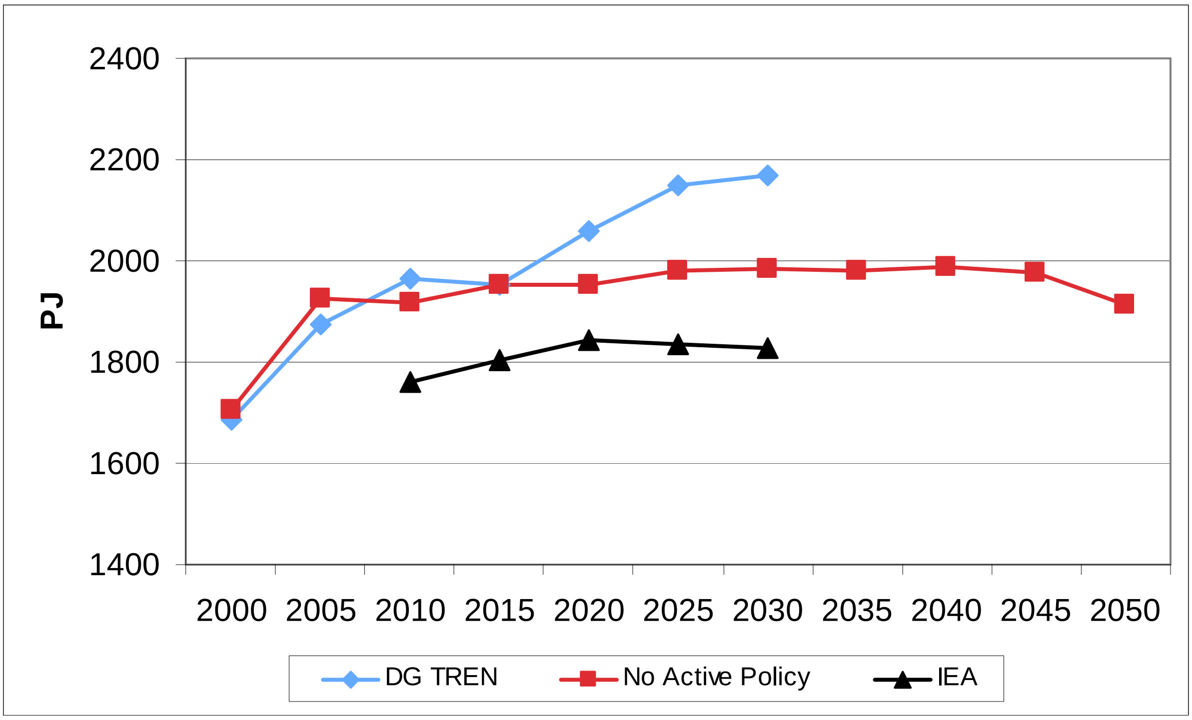


Sources: DG TREN 2008, Pačes 2008, IEA 2005a, own calculations.

3.2.4 Primary energy supply

As can be seen in Figure 13, primary energy supply in the *No Active Policy* scenario increases from 1,924 PJ in 2005 to 1,987 PJ in 2040, corresponding to an increase of 3%. In the following ten years primary energy supply decreases and reaches 1912 PJ in 2050 (- 1% over 2005).

Figure 13: Comparison of total primary energy demand in different reference scenarios (in PJ)



Sources: DG TREN 2008, IEA 2005a, own calculations.

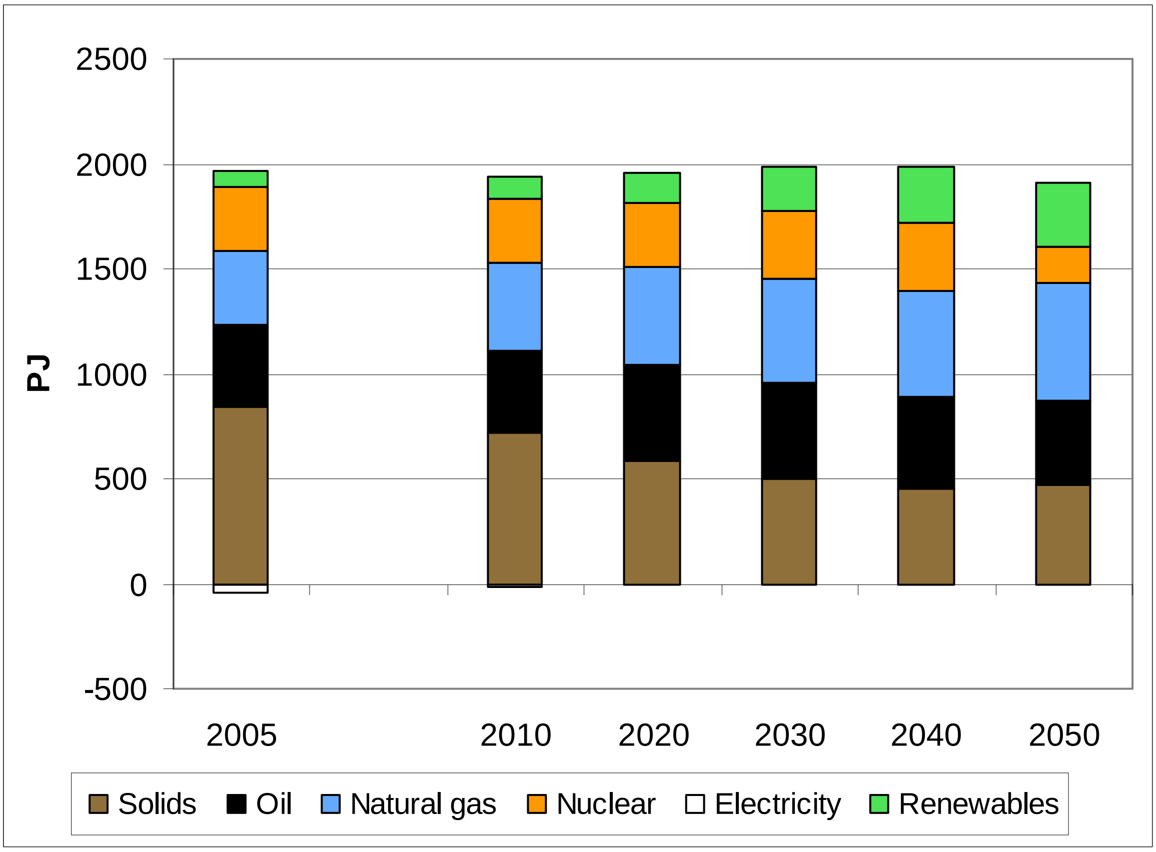
Primary energy supply stays virtually flat over the period as final energy demand rises (see Figure 6) but is roughly compensated for by improvements in energy conversion efficiency. Efficiency in electricity generation increases as the share of renewable sources and natural gas is increased at the expense of coal.[13] Also, the assumption that the Czech Republic reduces and (by 2020) eliminates its net electricity exports contributes to dampening primary energy demand. The drop in demand after 2040 is due to the slight decrease of final energy demand in those final years of the period examined, as well as the assumption that the Czech Republic becomes a net electricity importer from 2045 on.

Development of primary energy demand in the reference scenario of DG TREN is similar to our *No Active Policy* scenario until 2015 but increases stronger between 2015 and 2030, mainly due to assumed higher final energy demand in those years. Primary energy demand in the IEA (2005) scenario is much lower than in both other reference scenarios despite having similar final energy demand assumptions compared to our scenario. The main reason is likely the considerably lower future electricity demand expected by IEA compared to both the *No Active Policy* scenario and the reference scenario of DG TREN.

Figure 14 shows the sources of primary energy supply in 2005 and as modelled in the *No Active Policy* scenario for 10-year intervals starting in 2010.

[13] The common methodology used here to calculate primary energy from electricity generated from renewable sources like wind assumes a transformation efficiency of 100%.

Figure 14: Sources of primary energy supply (in PJ) in 2005 (actual) and in the *No Active Policy* scenario until 2050



Sources: DG TREN 2008, own calculations.

As the use of coal is reduced in both electricity generation as well as in final energy demand, its contribution to primary energy supply is steadily reduced until 2040, rising slightly again in the following ten years. Oil supply increases between 2005 and 2050 mainly as a consequence of increased demand for oil in the transport sector[14] and natural gas supply increases as its use is expanded in electricity generation as well as in final energy demand of all sectors. Nuclear energy use increases slightly until 2040 as a consequence of refurbishment measures at both nuclear power plants. From 2045 on its contribution decreases by almost 50% as nuclear power plant Dukovany is decommissioned. Renewable energy sources almost quadruple their contribution to primary energy supply between 2005 and 2050, rising from 79 PJ to 306 PJ. Stronger use of biomass is an important reason for this increase, as use of biomass is stepped up gradually in all sectors including transport, where bio-fuels contribute 16% of final energy demand in 2050. In addition biomass, solar energy, wind and geothermal heat all contribute significant amounts of electricity production and all individually produce more electricity than hydro power by 2050.

Figure 15 compares primary energy supply in the *No Active Policy* scenario with that in other reference scenarios. In 2030 primary energy supply in our scenario is lower than in the DG TREN scenario, which is mainly due to higher expected final energy demand and electricity

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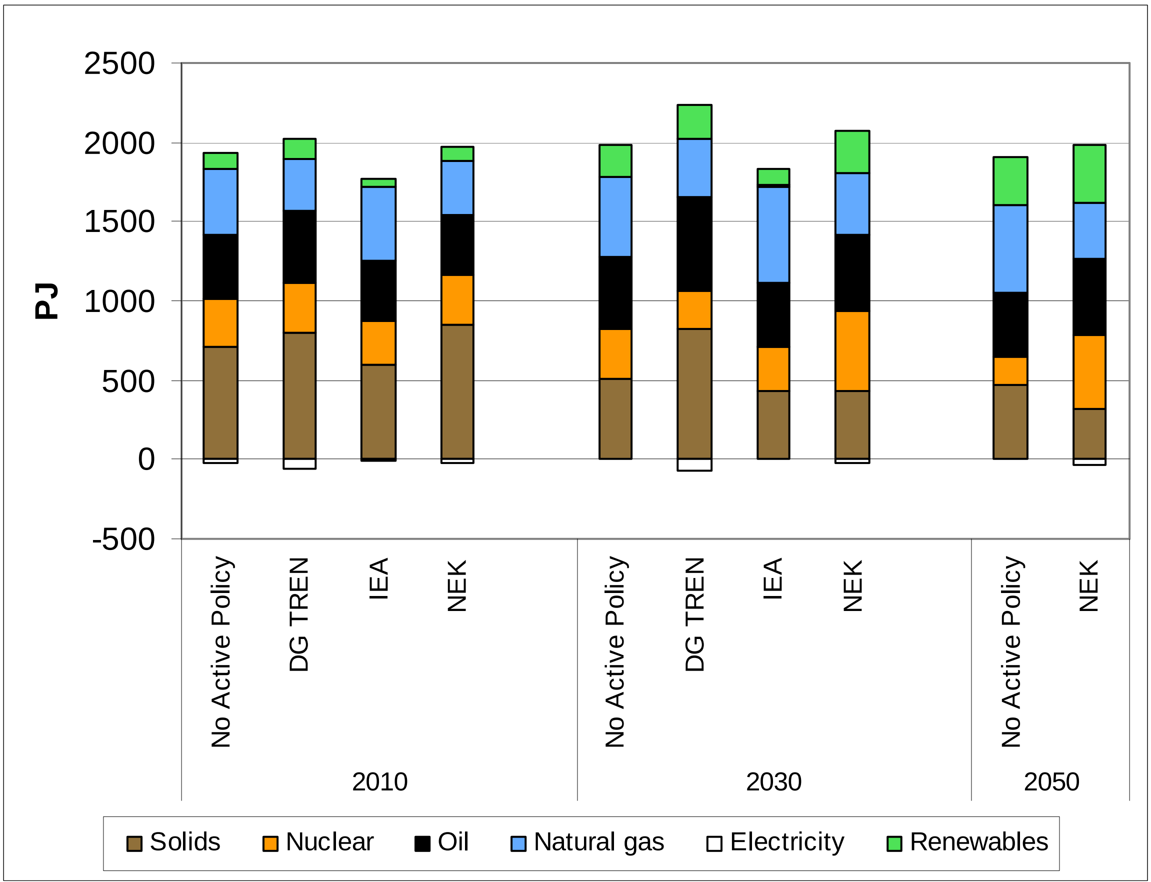
14 While the share of oil products in the transport sector gradually declines from 94% in 2005 to 69% in 2050, the strong increase in total transport sector energy demand (see Figure 7c) overcompensates this effect and increases demand for oil in that sector.

exports in the latter scenario (see Figure 6 and Figure 9). The IEA scenario's primary energy supply is lower than the supply in our scenario, despite somewhat higher final energy demand. This can be explained by the lower amount of electricity consumption in the IEA scenario (see Figure 8).[15] Not surprisingly, as the *No Active Policy* scenario uses final energy demand data from the baseline scenario of the Independent Energy Commission, both scenarios' primary energy supply is similar.

Figure 15: Comparison of primary energy supply by source in different reference scenarios (in PJ)



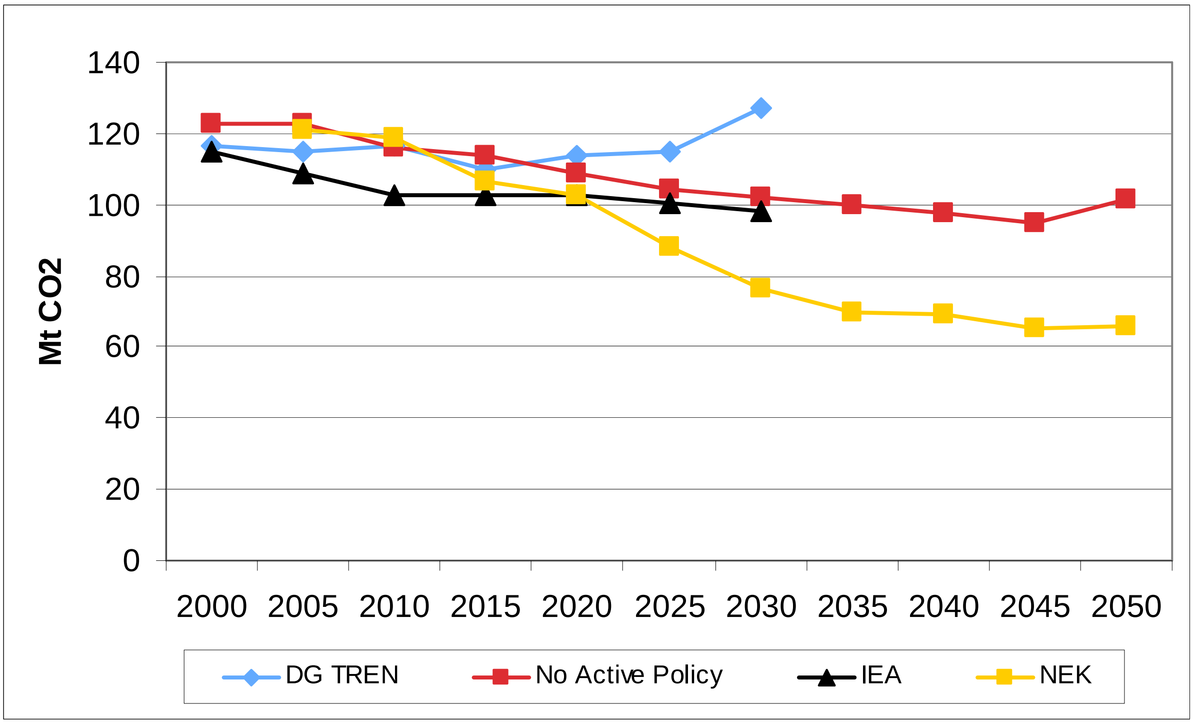
Sources: DG TREN 2008, Pačes 2008, IEA 2005a, own calculations.

3.2.5 CO_2 emissions of the energy sector

Figure 16 shows energy-related CO_2 emissions of the *No Active Policy* scenario as well as other reference scenarios. Emissions in our scenario decline relatively steadily between 2005 and 2045 before rising again in 2050 as the decommissioning of Dukovany is compensated for in large part by additional use of coal and gas in power generation. Between 2005 and 2050 CO_2 emissions go down from 122 Mt to 102 Mt, a decline of 17%.

15 Due to the average energy transformation losses in electricity generation, electricity requires more primary energy per unit than other types of final energy demand.

Figure 16: Comparison of energy-related CO_2 emissions (in Mt) between different reference scenarios



Sources: DG TREN 2008, Pačes 2008, IEA 2005a, own calculations.

Several reasons can be identified for the decline in energy-related CO_2 emissions despite growing final energy demand:

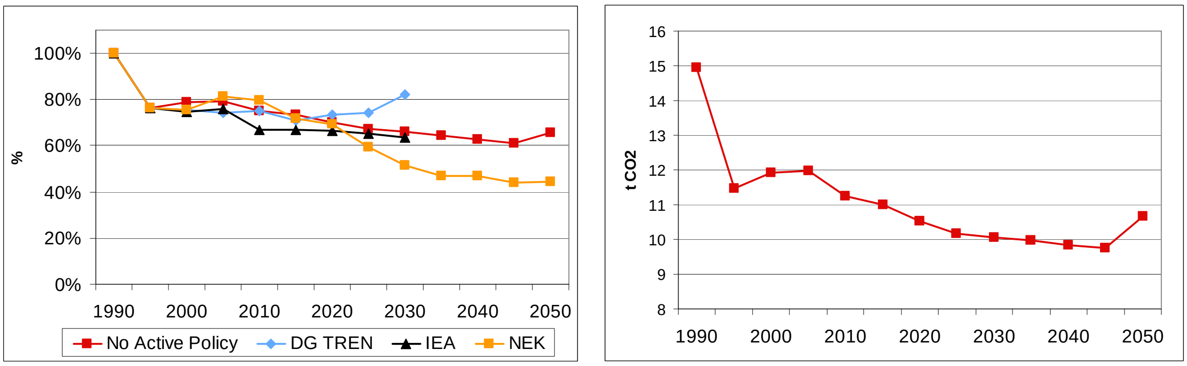
- The use of low carbon and carbon-free renewable energy sources increases considerably throughout the observed period and throughout all sectors.
- Efficiency of existing and especially of new coal power plants is increased. Average coal power plant efficiency increases from about 33% in 2005 to 43% in 2050. Power plant technologies for other energy sources also improve their efficiency.
- Use of the much more efficient combined heat and power (CHP) technology is increased. Electricity from CHP rises to about 27% in 2025 (compared to less than 17% in 2005) and remains between 25% and 28% until the end of the observed period.
- Some of the highly carbon-intensive coal is replaced by less carbon-intensive natural gas.

As Figure 16 shows, CO_2 emissions in the *No Active Policy* scenario in 2030 are similar to those of the IEA (2005) reference scenario. In contrast, from 2020 on they are considerably below CO_2 emissions in the DG TREN (2008) reference scenario. In that scenario final energy demand is higher and renewable energy utilisation lower, thus explaining the difference in emissions. CO_2 emissions in the baseline scenario of the report of the Independent Energy Commission (NEK) decline much faster than in our scenario, especially after 2020. This is mainly due to the assumption made in that scenario that additional nuclear power plant capacity is build around 2025 and that the use of renewables is expanded further compared to the *No Active Policy* scenario.

Figure 17a shows the development of CO_2 emissions in various reference scenarios relative to 1990 emissions. Relative to 1990, emissions in the *No Active Policy* scenario are reduced by 34% in the year 2050 while the baseline scenario of the Independent Energy Commission reaches a reduction of 55%. For our scenario this corresponds to a drop of annual per capita emissions from 15 tons in 1990 (12 tons in 2005) to just under 11 tons in 2050 (see Figure 17b). According to climate scientists, in order to prevent the worst consequences of climate change, this is far above the acceptable per capita emissions in 2050.

Figures 17a, b: Comparison of the development of CO_2 emissions (indexed, 1990 = 100%) in different reference scenarios [a] and annual per capita CO_2 emissions (in t) in the *No Active Policy* scenario [b]

a **b**



Sources: DG TREN 2008, Pačes 2008, IEA 2005a, own calculations.

3.3 Existing estimates for additional energy efficiency and renewable energy potential

3.3.1 Energy efficiency

As a first step for the development of alternative energy scenarios we've looked at various existing studies and scenarios evaluating energy efficiency potential as well as renewable energy potential in the Czech Republic. Such estimates indicate what is potentially achievable through appropriate and stringent policies in the field of both, energy efficiency and renewable energy expansion.

Three scenarios are available, estimating how much total final energy demand in the Czech Republic can be reduced by tapping existing energy efficiency potentials:

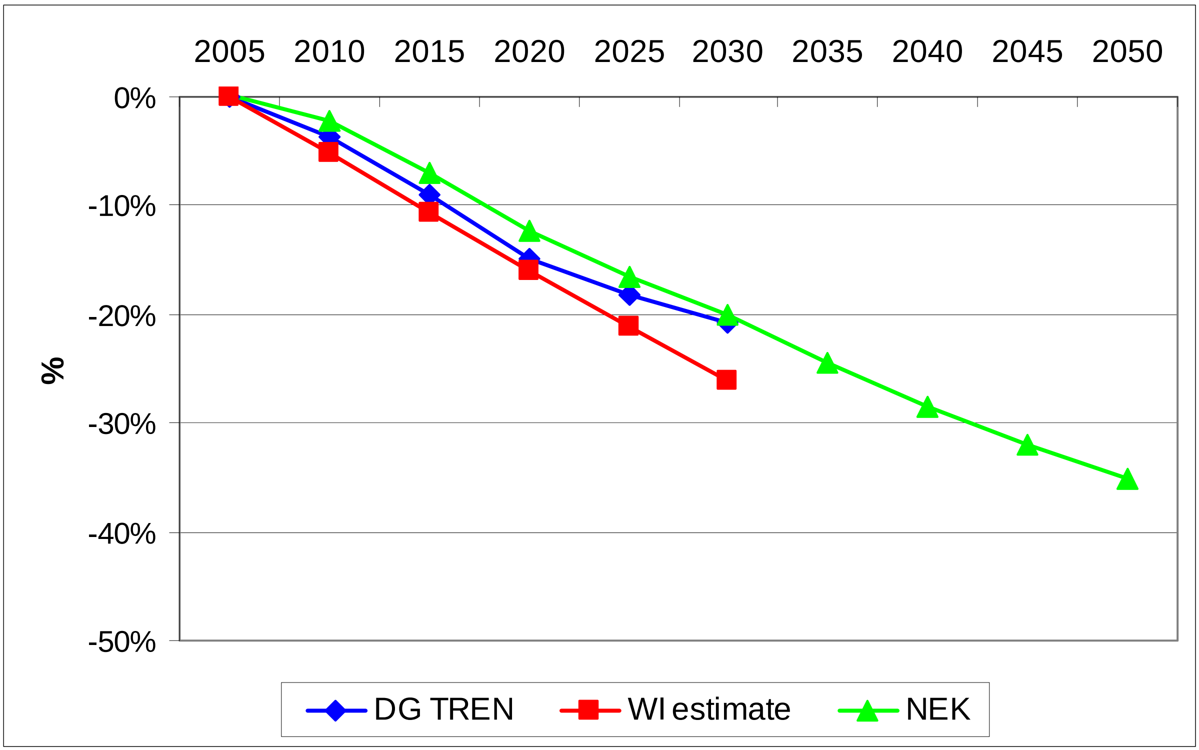
- Final energy demand data from *Scenario E* of the Independent Energy Commission's report. *Scenario E* assumes that ambitious energy efficiency measures are enacted to reduce final energy demand. The scenario runs until 2050.
- Data from the scenario *Combined high renewables and efficiency* for the Czech Republic from the European Commission's report "European Energy and Transport – Scenarios on energy efficiency and renewables". The study was released in 2006 (DG TREN 2006) and its scenarios run until 2030.
- Existing estimates from the Wuppertal Institute provide technical demand side energy efficiency potential for the Czech Republic until 2030 for all sectors.

In addition we have looked at bottom-up estimates of the current (static) technical efficiency potential in the industry sector of the Czech Republic (Truxa et al 2008) as well as at bottom-up studies estimating the long-term (dynamic) efficiency potential in the household sector (Šafařík / Klusák 2007a) and the tertiary sector (Šafařík / Klusák 2007b).

Figure 18 compares the estimated energy efficiency potentials of the three scenarios that provide data on total final energy demand. Their efficiency potential is shown in relation to final energy demand projected in the different[16] baseline scenarios of the respective studies. Estimated energy efficiency potentials compared to reference development are similar in all three scenarios by 2030. *Scenario E* of the report of the Independent Energy Commission (NEK) and the "Combined high renewables and efficiency" scenario of DG TREN (2006) both assume that total final energy demand in 2030 could be one fifth below demand in the respective reference scenarios. Estimates from Wuppertal Institute are somewhat lower at -26% compared to the reference scenario in 2030.

[16] When comparing the data in Figure 18 it should be kept in mind that final energy demand throughout the baseline scenarios of the three studies are different.

Figure 18: Comparison of total final energy demand of different energy efficiency potential estimates over their respective baselines



Sources: DG TREN 2006, SEVEn 2008, own calculations.

Scenario E of the Independent Energy Commission is the only scenario available that provides data until 2050. By then final energy demand is 35% below final energy demand of the reference scenario (*Scenario C*) of the commissions.

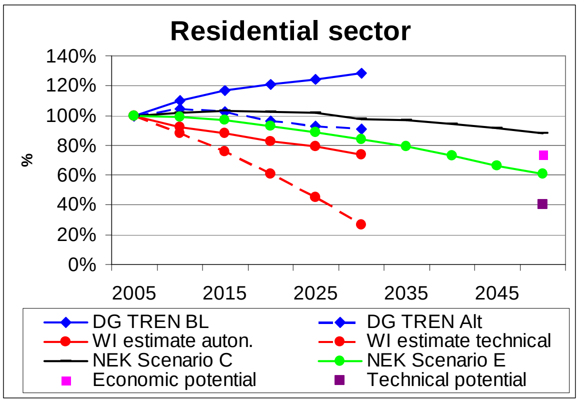
Figures 19a-d show final energy demand in the different sectors as projected by various reference scenarios and energy efficiency scenarios in index form (2005 = 100%).[17] The figures show that there are indications from the different scenarios and efficiency estimates that in some fields the potential of energy savings from energy efficiency could be higher than projected by *Scenario E* of the Independent Energy Commission. However, *Scenario E* data appears more ambitious than all other scenarios in some sectors (transport and industry).

For this report's first alternative scenario, called *Slow Progress* scenario, we have decided not to assume efficiency improvements exceeding those assumed in *Scenario E* of the Independent Energy Commission's report. We have thus used final energy demand data from *Scenario E*.

17 Sources for data indicated as "Economic potential" and „Technical potential" are three Czech studies on different energy sectors (Truxa et al 2008, Šafařík / Klusák 2007a and Šafařík / Klusák 2007b).

Figures 19a-d: Comparison of final energy demand in the various sectors in different reference scenarios, energy efficiency scenarios and bottom-up potential studies (2005 = 100)

a



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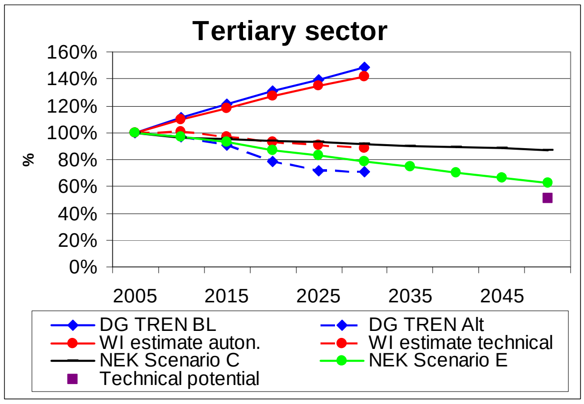

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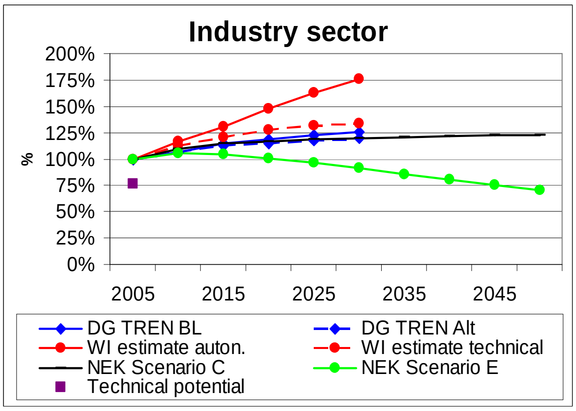

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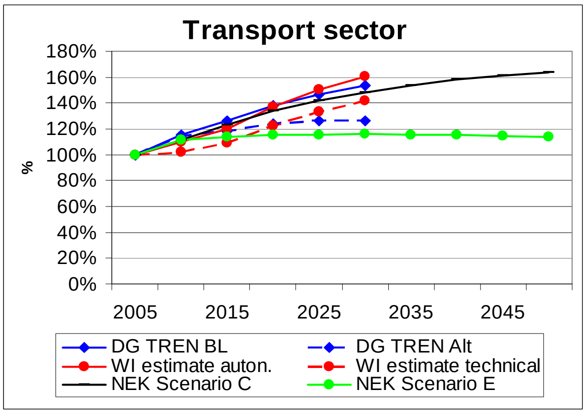


Sources: DG TREN 2006, DG TREN 2008, SEVEn 2008, Šafařík / Klusák 2007a, Šafařík / Klusák 2007b, Truxa 2008, own calculations.

These comparisons with other efficiency potential data indicate that the energy savings through efficiency as described in *Scenario E* of the Independent Energy Commission's report are ambitious but not overambitious and should be realisable through appropriate energy efficiency policy measures.

3.3.2 Renewable energies

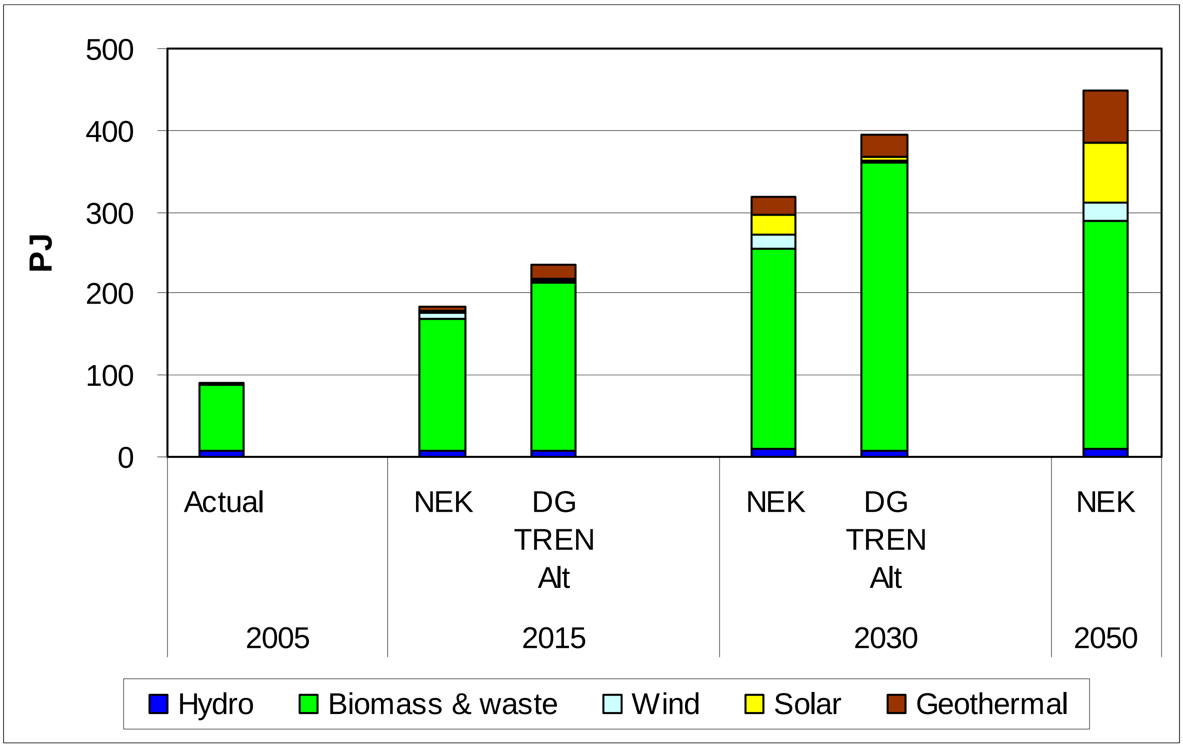
Concerning renewable energy potential we looked at three different scenarios that aim to maximise the use of the various sources of renewable energy:

- The chapter on renewable energies in the report of the Independent Energy Commission includes potential estimates for all renewable energy sources.
- As the name of the scenario indicates, the *Combined high renewables and efficiency* scenario of the European Commission's report (DG TREN 2006) assumes that strong policies for the support of renewable energies are implemented successfully.

- The *OPTRES* project (Resch et al 2006) evaluated the maximum contribution renewable energy sources can make to the electricity supply in the Czech Republic (as well as other European countries) until 2020.

Figure 20 looks at the potential contribution of renewable energy sources to primary energy supply. As the *OPTRES* project provides data only for electricity and not for primary energy, Figure 20 compares only the data from the report of the Independent Energy Commission (NEK) and the data from the DG TREN (2006) scenario.

Figure 20: Comparison of renewable energy contribution to primary energy supply by source in different high-renewable scenarios (in PJ)

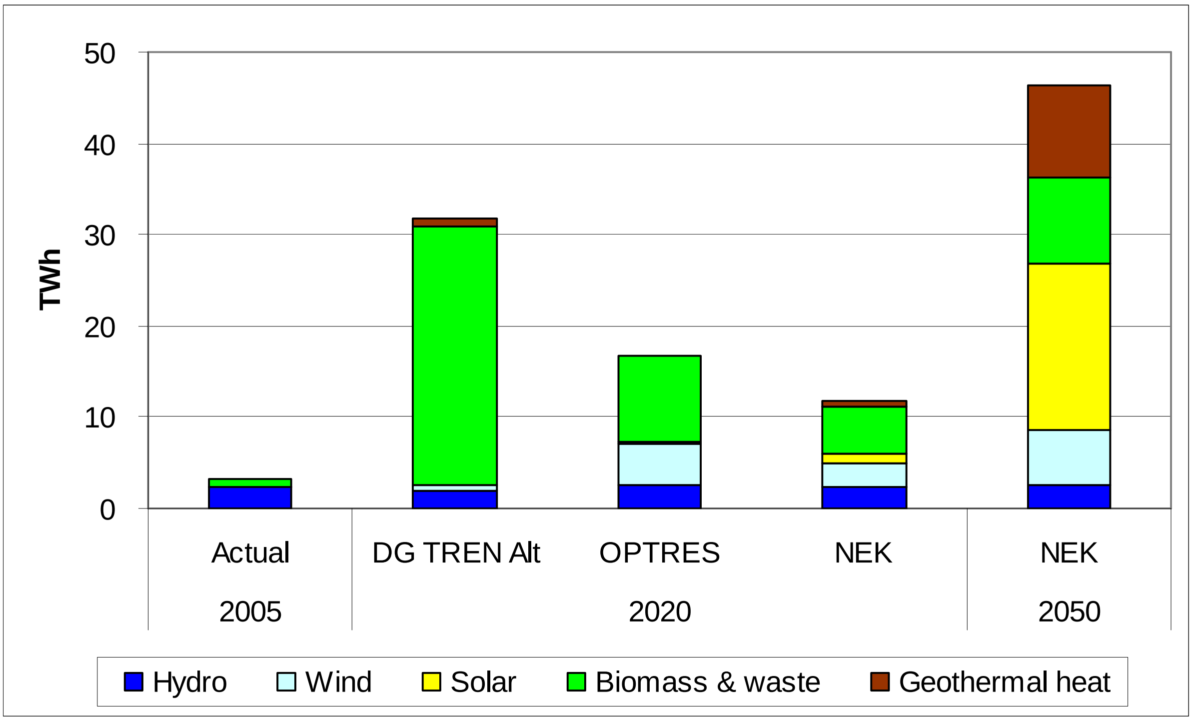


Sources: DG TREN 2006, DG TREN 2008, Pačes 2008.

As can be seen in Figure 20, renewable energy supply could more than triple or even quadruple until 2030 compared to 2005 according to available scenarios. The Independent Energy Commission concludes that renewable energy supply in 2050 could be 448 PJ compared to 90 PJ in 2005, corresponding almost to a 400% increase. Biomass remains by far the most important renewable energy source over the entire observed period in both scenarios. However, there is disagreement between both sources on how fast biomass use can be expanded and what is the limit of its use. While in the DG TREN scenario more than 350 PJ of biomass are used in the year 2030, the Independent Energy Commission foresees that just 246 PJ are used that year and only a relatively small increase to 280 PJ is expected over the following 20 years. On the other hand the Independent Energy Commission is more optimistic regarding the future contribution of solar energy, which in 2050 makes up 17% of all renewable energy, and wind energy, which in the same year makes up 5%. Both DG TREN and the Independent Energy Commission expect geothermal heat to contribute to primary energy supply in the coming decades, while DG TREN expects geothermal potential to be realized somewhat faster. Both sources do not see any potential to significantly expand hydro power.

Figure 21 looks at renewable energy sources in electricity generation and also includes data for 2020 from the *OPTRES* project's study. Not surprisingly, similar to the figures on the primary energy side, the DG TREN scenario is by far the most optimistic one when it comes to expanding renewable energy use in the electricity sector. Again this is due to the high use of biomass. The *OPTRES* data on the other hand sees a higher potential for wind energy already by the year 2020 than both other scenarios. Interestingly, the potential estimates of the Independent Energy Commission (NEK) for renewables in the electricity sector are well below those of both DG TREN and *OPTRES*. The reason for this is the less aggressive expansion of biomass use. However, unlike in the other two scenarios, in the Independent Energy Commission's data electricity from photovoltaics already plays a role by 2020.

Figure 21: Comparison of contribution of renewable energy to electricity supply by source in different high-renewables scenarios (in TWh)



Sources: DG TREN 2006, DG TREN 2008, Pačes 2008, Coenraads et al 2006.

Looking at 2050, the Independent Energy Commission expects a relatively even contribution of the different sources of renewable energy to electricity generation with solar energy having the biggest share and geothermal energy, biomass and wind power all making sizeable contributions. All in all the Independent Energy Commission expects electricity from renewables to rise from 3.1 TWh in 2005 to 11.7 TWh in 2050, a rise of more than 370%.

For the *Slow Progress* scenario we have decided to use renewable energy potential estimates from the Independent Energy Commission's report.[18] While other studies running until 2020 or 2030 assume higher use of renewables (see Figure 20 and Figure 21), it is difficult to asses whether the strong expansion of biomass described in those scenarios can in fact be realised in a sustainable manner. At the same time, while future technological develop-

18 We have also decided to use these assumptions about renewable energy potential (and not more optimistic assumptions) in the more ambitious *Innovative Approach* scenario (see below).

ment of solar and geothermal heat conversion technologies is relatively uncertain, we believe that the contributions of these conversion technologies as described in the report of the Independent Energy Commission are feasible, given appropriate political support is provided in time.

3.4 Slow Progress scenario

3.4.1 Major Assumptions

As described above we have used potential data for the contribution of renewable energy to both primary energy and electricity supply from the report of the Independent Energy Commission (Pačes 2008). We assume in the *Slow Progress* scenario that appropriate policy measures (see below and chapter 4.2) will be enacted in the Czech Republic in a timely manner and that this will help to achieve the potential as described by the Independent Energy Commission's report. Thus Figure 20 and Figure 21 show the contribution of renewable energy sources in the *Slow Progress* scenario (identical to data indicated by "NEK").

Other major assumptions the *Slow Progress* scenario is based on are the following:

- No use of Carbon Capture & Storage (CCS) is assumed as this technology has not yet been demonstrated for power plants or industrial plants at a large scale. It is thus unclear whether CCS will be technically and economically viable and whether CO_2 storage capacity will be sufficient.

- No new nuclear power plants will be built in the Czech Republic. This avoids increasing the risks and problems associated with nuclear power and it also takes into account the flexibility of the electricity supply structure needed in a high-renewable energy system.

- As the risk of incidences at nuclear power plants can be expected to increase with the ageing of the plants, we assume that both nuclear plants currently in operation will be decommissioned once they reach an age of about 40 years. This means that the old nuclear power plant Dukovany will be decommissioned by 2030 (as was originally planned) while the newer plant Temelín will be in operation until 2045.

- From 2030 on the Czech Republic will start importing electricity from renewable energy sources, mostly from solar thermal power plants in North Africa.

3.4.2 Final energy demand

3.4.2.1 Total final energy demand

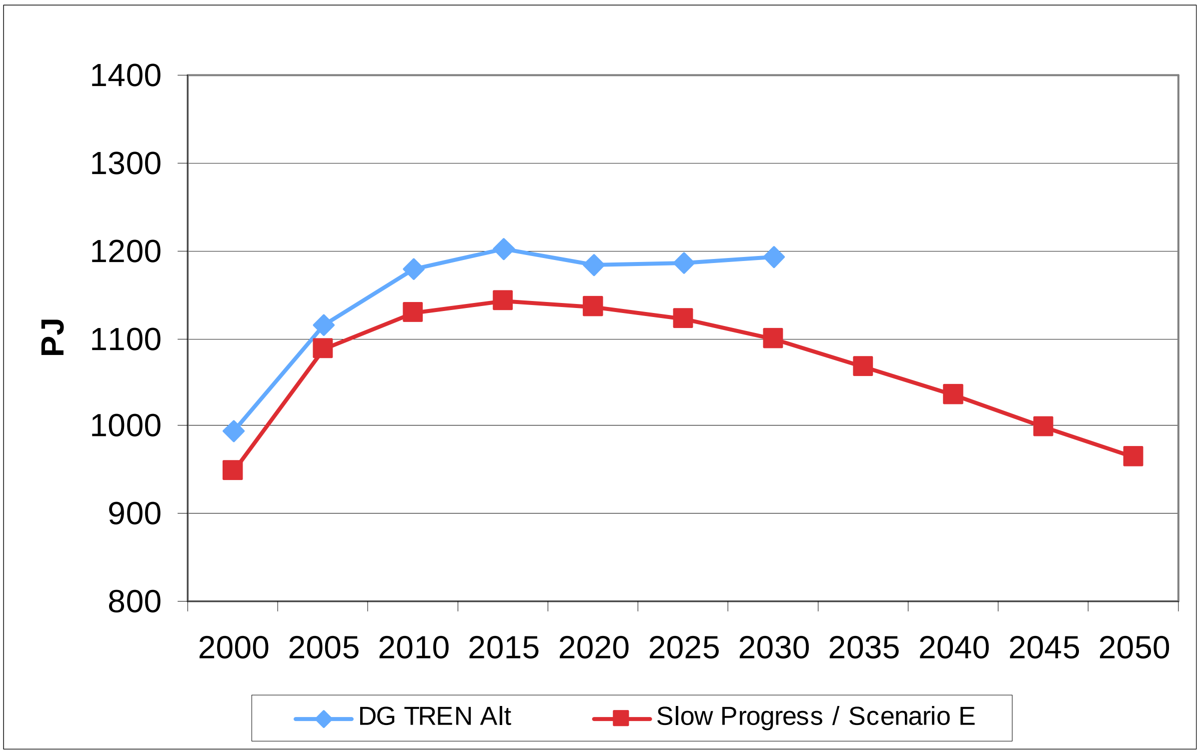
Total final energy demand as described by *Scenario E* of the Independent Energy Commission's report is shown in Figure 22.[19] Demand is expected to increase more slowly from 2005

[19] As we have used final energy demand data from Scenario E of the Independent Energy Commission's report, information on total as well as sectoral final energy demand in our alternative scenario can be derived from Figure 18 and Figures 19a-d above (data indicated by "NEK").

to 2015 (compared to its increase in recent years) and to decrease afterwards. By 2050 it will have almost gone back to its 2000 level and it will be 11% below its value in 2005.

Figure 22 compares total final energy demand in the *Slow Progress* scenario with demand in the alternative scenario of DG TREN. As can be seen, total final energy demand is higher in the DG TREN scenario until 2030 and it decreases only between 2015 and 2020, while growing again in the following years.

Figure 22: Comparison of total final energy demand in different alternative scenarios (in PJ)



Sources: DG TREN 2006, SEVEn 2008.

Final energy demand in the *Slow Progress* scenario is lower than in the *No Active Policy* scenario in all sectors (see Figures 23a-d).

Figures 23a-d: Comparison of final energy demand in the different sectors in the *Slow Progress* scenario and the *No Active Policy* scenario (in PJ)

Source: SEVEn 2008.

In the household sector (see Figure 23a) stricter standards on the insulation of new buildings and a higher refurbishment rate of existing buildings help to realize significant energy savings. By 2050, average heating consumption will have decreased to 74 kWh/m^2 per year, compared to 117 kWh/m^2 in the *No Active Policy* scenario and compared to today's 185 kWh/m^2. In addition, heat exchangers for waste water are assumed to be used after the year 2020, helping to reduce heat demand for hot water in 2050 from 13 GJ per household and year in the *No Active Policy* scenario to 10 GJ in the *Slow Progress* scenario.[20] While electricity consumption for electric appliances will increase until 2015 as the amount of appliances in households increases, policies to encourage or mandate the use of highly-efficient electric appliances will eventually lead to a reduction in their total electricity demand. Average consumption will decrease from 6 GJ per household and year in 2005 to 4.2 GJ in 2050. In the *No Active Policy* scenario demand only falls to 5.85 GJ in 2050.

[20] In 2005 energy demand for hot water in households was 15.5 GJ.

In the tertiary sector (see Figure 23b) energy savings over the *No Active Policy* scenario are realized for the same reasons: The insulation of buildings is improved, leading to a heating demand of 72 kWh/m^2 instead of 109 kWh/m^2. Hot water is used more efficiently and much more efficient electric appliances are used.

In the industrial sector (see Figure 23c) various manufacturing processes are responsible for the bulk of energy demand. Energy efficiency of these processes is considerably increased in the *Slow Progress* scenario compared to the *No Active Policy* scenario. Energy intensity in the *Slow Progress* scenario is reduced on average by 3% per year compared to just 1.2% in the *No Active Policy* scenario. One way to realize higher reductions in energy intensity is to assume higher world market energy prices. However, as our study assumes identical external conditions for all three scenarios, we assume that either domestic energy prices are increased through appropriate political measures or alternatively that ambitious energy efficiency standards are implemented for the different industrial branches.

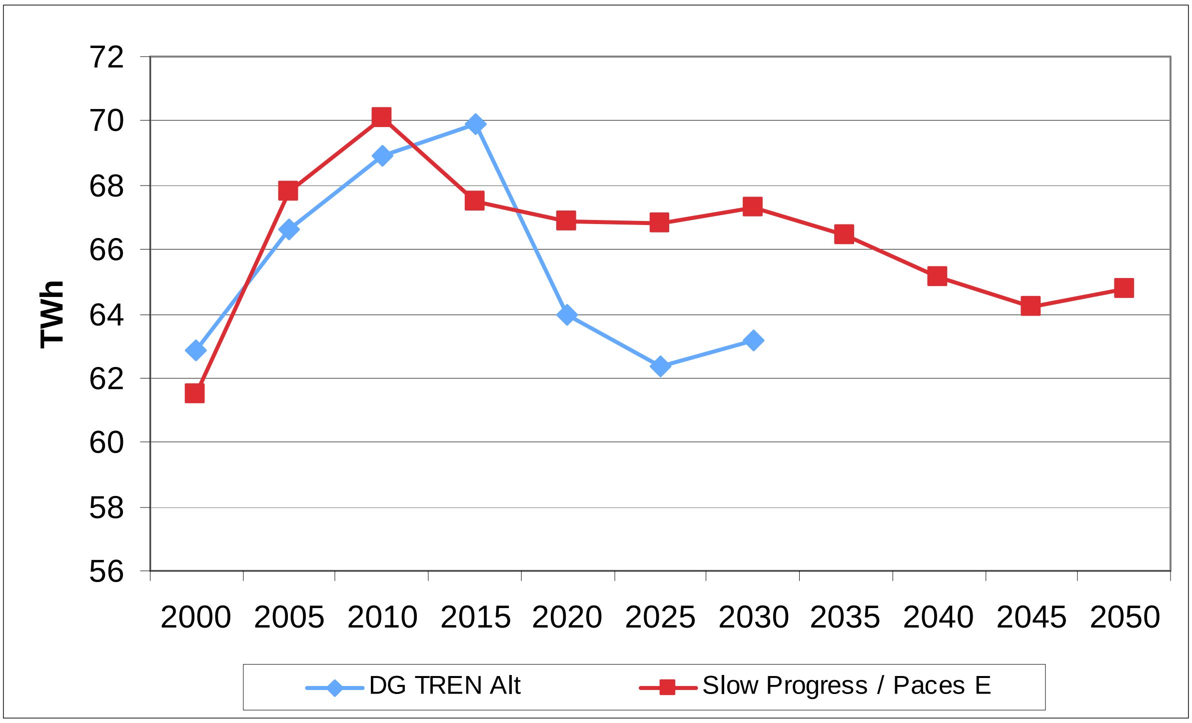
Final energy demand in the transport sector (see Figure 23d) is reduced compared to the *No Active Policy* scenario as demand for both passenger as well as freight transportation is assumed to grow by less. In addition, new and more efficient technologies are assumed to be used more widely. For example in the *Slow Progress* scenario cars that are primarily used within cities will be mostly hybrid or electric vehicles. It is assumed that transport infrastructure is optimized to increase overall efficiency and decrease specific fuel consumption.

3.4.3 Electricity consumption and electricity supply

3.4.3.1 Electricity consumption

Figure 24 shows electricity consumption in the *Slow Progress* scenario (equivalent with electricity consumption in *Scenario E* of the Independent Energy Commission's report) and in the alternative scenario of DG TREN (2006). In the *Slow Progress* scenario electricity consumption continues to rise until 2010 and then declines as a result of efficiency measures until 2045 before rising again in the following five years. The decline in electricity consumption from 2010 to 2045 is due to the assumed increase in efficiency of electric appliances and machinery in the household, tertiary and industrial sectors (see chapter 3.4.2.1). The rise at the end of the observed period is due to a significant increase in electricity demand in the transport sector, in which electricity increases to make up more than 10% of final energy demand in 2050 (compared to 3% in 2005). The DG TREN alternative scenario expects electricity consumption to peak five years later but to then drop off much stronger in the following years.

Figure 24**:** Comparison of electricity consumption in different alternative scenarios (in TWh)

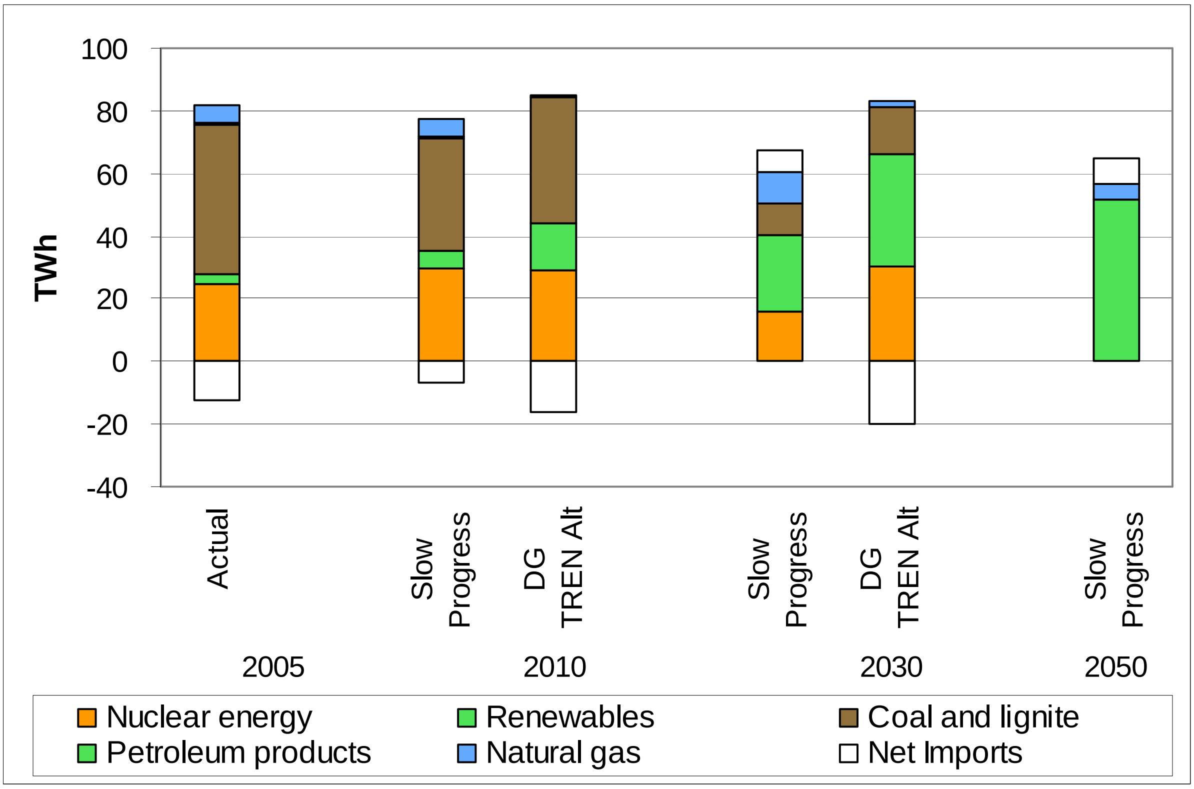


Sources: DG TREN 2006, SEVEn 2008.

3.4.3.2 Electricity production

Figure 25 shows gross electricity production and net electricity imports in 2005, projected gross electricity production and net electricity imports in the *Slow Progress* scenario for the years 2010, 2030 and 2050 and the same data for the DG TREN alternative scenario for the years 2010 and 2030. Electricity demand in the DG TREN alternative scenario is similar to the *Slow Progress* scenario but much more electricity is generated as net exports are expanded compared to exports in 2005 while we assume that from 2020 on there will be no more net electricity exports by the Czech Republic. In the *Slow Progress* scenario renewable energy sources are increasingly used to generate electricity and by 2050 almost 70% of all electricity generated and imported comes from domestic renewable energy sources. Imports from electricity generated abroad from renewable sources (especially solar thermal power plants) start in 2030 in order to help compensate for the decommissioning of nuclear power plant Dukovany. By 2050 8.3 TWh of renewable electricity is imported, representing 13% of total electricity supply (gross electricity production plus electricity imports) in that year.

Figure 25: Comparison of gross electricity generation by source and net electricity imports in different alternative scenarios (in TWh)



Sources: DG TREN 2006, DG TREN 2008, own calculations.

Table 2 shows the average efficiencies of electricity production of newly-built and of all existing non-CHP power plants as well as average efficiencies of electricity and heat production of newly-built and of all existing CHP power plants.[21] As in the *Slow Progress* scenario the use of renewable energy is expanded quickly and electricity consumption declines after 2010, no new non-CHP coal or gas power plants are needed. Also from 2030 on, no more new con-CHP biomass plants are built. As a consequence, after 2030 there are only few non-CHP coal power plants and virtually no such gas power plants left in operation. Also as a consequence of little to no additional plants being built, the existing plants' average efficiencies are actually lower in the *Slow Progress* scenario than in the *No Active Policy* scenario. Newly-built CHP plants are assumed to be a little more efficient in the *Slow Progress* scenario compared to the *No Active Policy* scenario, as either market-based policies or standards requiring the use of best available technology lead to companies investing only in the most efficient power plant technology.

21 In Table 2 dashes instead of figures indicate that no new power plants of the respective type are built or in operation at that time.

Table 2: Average efficiencies of electricity (and heat) production in different types of non-CHP and CHP power plants in the *Slow Progress* scenario

Newly-built non-CHP plants

	2005-2010	2015-2020	2025-2030	2035-2040	2045-2050
coal	-	-	-	-	-
gas	-	-	-	-	-
biomass	31%	33%	35%	-	-

All existing non-CHP plants

	2010	2020	2030	2040	2050
coal	34%	34%	35%	40%	40%
gas	34%	37%	39%	-	-
biomass	28%	31%	33%	34%	34%

Newly-built CHP plants

	2005-2010	2015-2020	2025-2030	2035-2040	2045-2050
coal	75%	78%	79%	-	-
gas	82%	84%	87%	89%	-
biomass	80%	81%	83%	84%	-

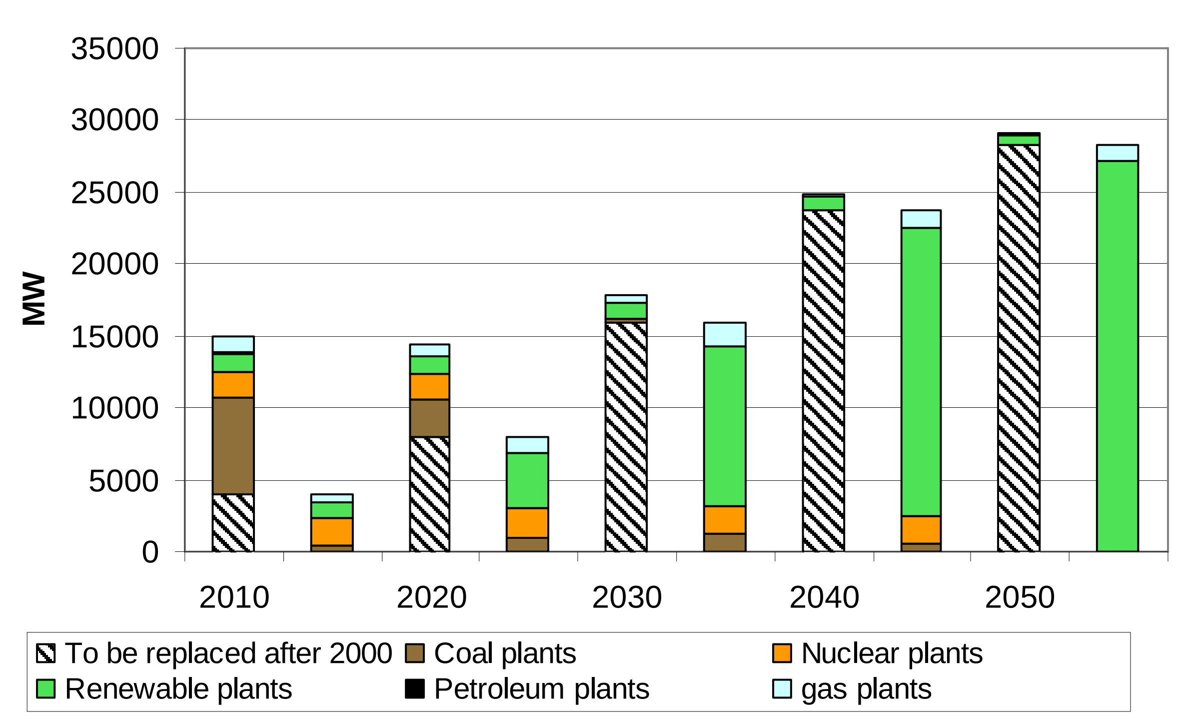
All existing CHP plants

	2010	2020	2030	2040	2050
coal	69%	72%	77%	77%	77%
gas	80%	82%	83%	83%	83%
biomass	72%	76%	78%	79%	79%

Sources: IEA 2008a, own calculations.

Figure 26 shows that in the *Slow Progress* scenario from 2020 on most of the power plant capacity that needs to be replaced after the year 2000 will have been replaced by renewable energy plants. As the nuclear plant Temelín was completed after 2000, it is also depicted in Figure 26 (until it is decommissioned around 2045). Some gas power capacity as well as some coal power capacity (in the form of CHP plants) will also be built, especially in the early part of the observed period.

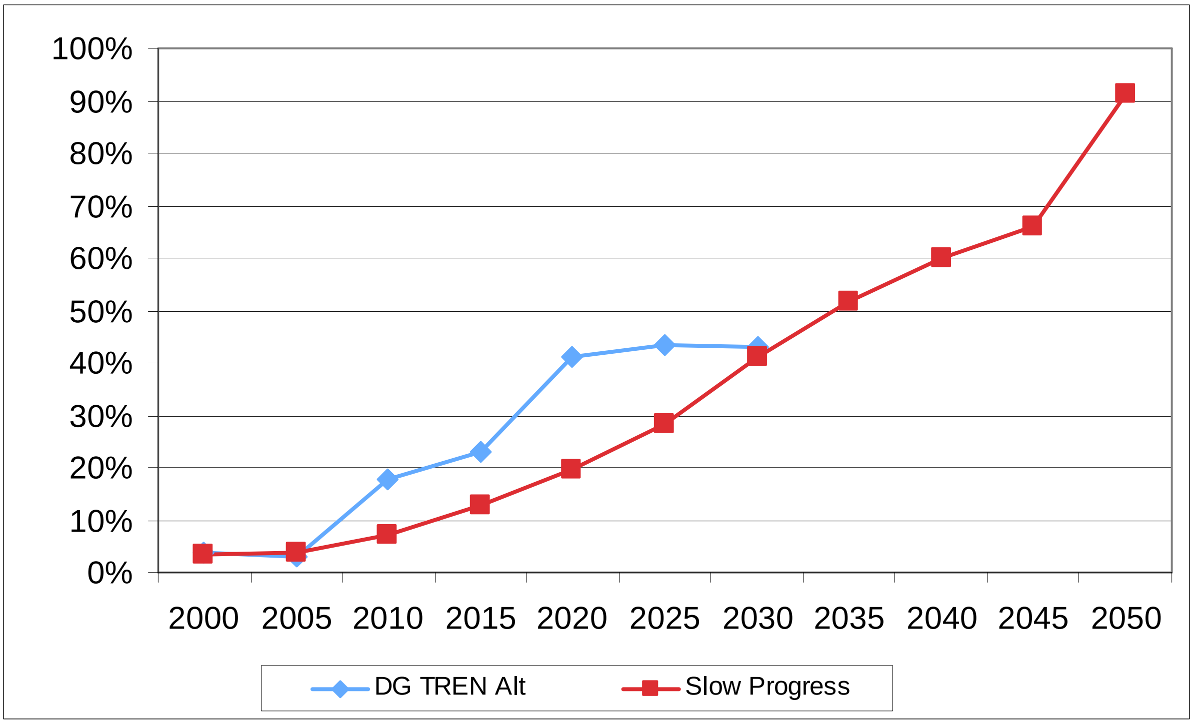
Figure 26: Power plant capacity in the *Slow Progress* scenario (in MW, including CHP) with separate depiction of capacity added after the year 2000



Source: Own calculations.

Figure 27 shows the share of renewable energy in domestic electricity generation. In the *Slow Progress* scenario this share rises steadily to reach 41% in 2030 and 91% in 2050, up from 4% in 2005. The share in DG TREN's alternative scenario in 2030 is similar at 43% but the share rises much faster until 2020 than in the *Slow Progress* scenario before it stagnates after 2020 at just over 40%. DG TREN's alternative scenario assumes that electricity generation from biomass can be expanded significantly within the next 10 to 15 years. After 2020 however, there is little more growth of biomass generation expected and other renewables like wind and geothermal energy also don't grow much after 2020. The *Slow Progress* scenario expects biomass power generation to rise relatively steadily until 2040 and well before then other renewable sources, especially solar energy and geothermal energy have started to significantly increase their contribution to electricity generation, allowing the share of all renewables to continue to rise.

Figure 27: Comparison of share of renewable energy in domestic electricity generation in different alternative scenarios (in %)



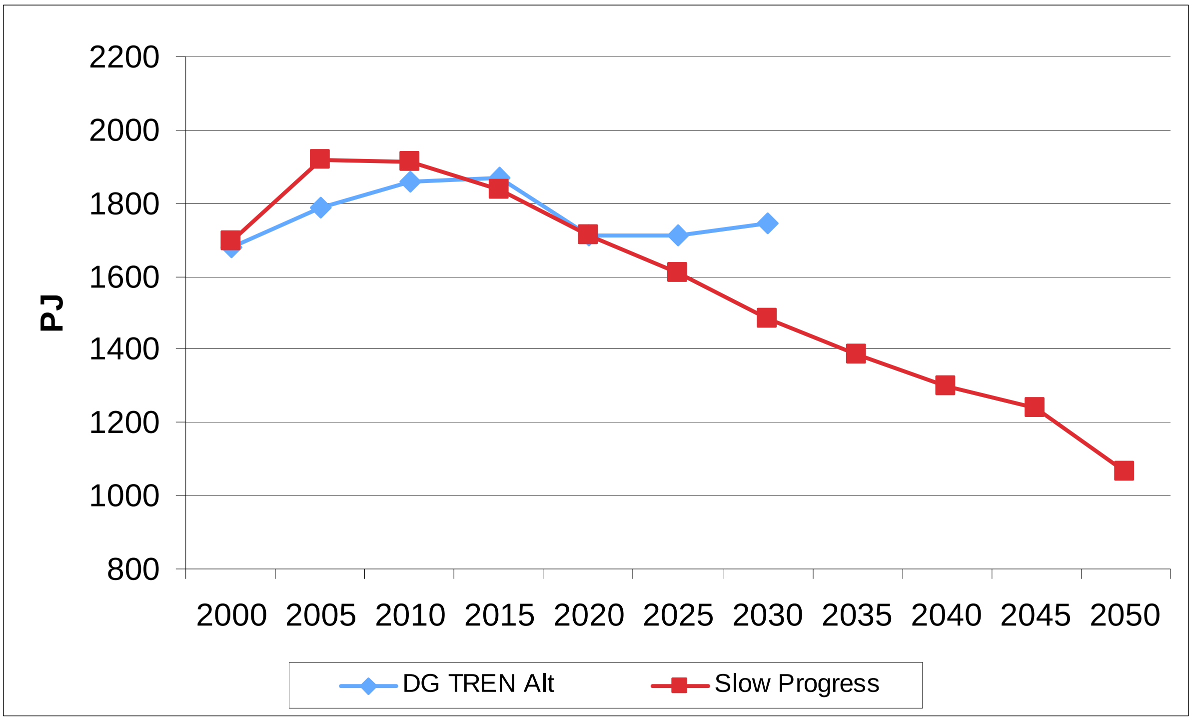
Sources: DG TREN 2006, own calculations.

3.4.4 Primary energy supply

As Figure 28 shows, primary energy supply in the *Slow Progress* scenario decreases significantly from today's levels. Compared to 2005 it is 23% lower in 2030 and 45% lower in 2050. Compared to DG TREN's alternative scenario the development of primary energy supply is similar until the year 2020[22] but in our scenario continues to decrease afterwards while it increases in the DG TREN study. This can be explained by the difference in the trend of final energy demand after 2020 (see Figure 22) as well as the electricity exports expected in the DG TREN scenario (see Figure 24).

22 With the exception of the year 2005 in which the DG TREN study released in 2006 did not have actual data and underestimated the increase in primary energy supply compared to the year 2000.

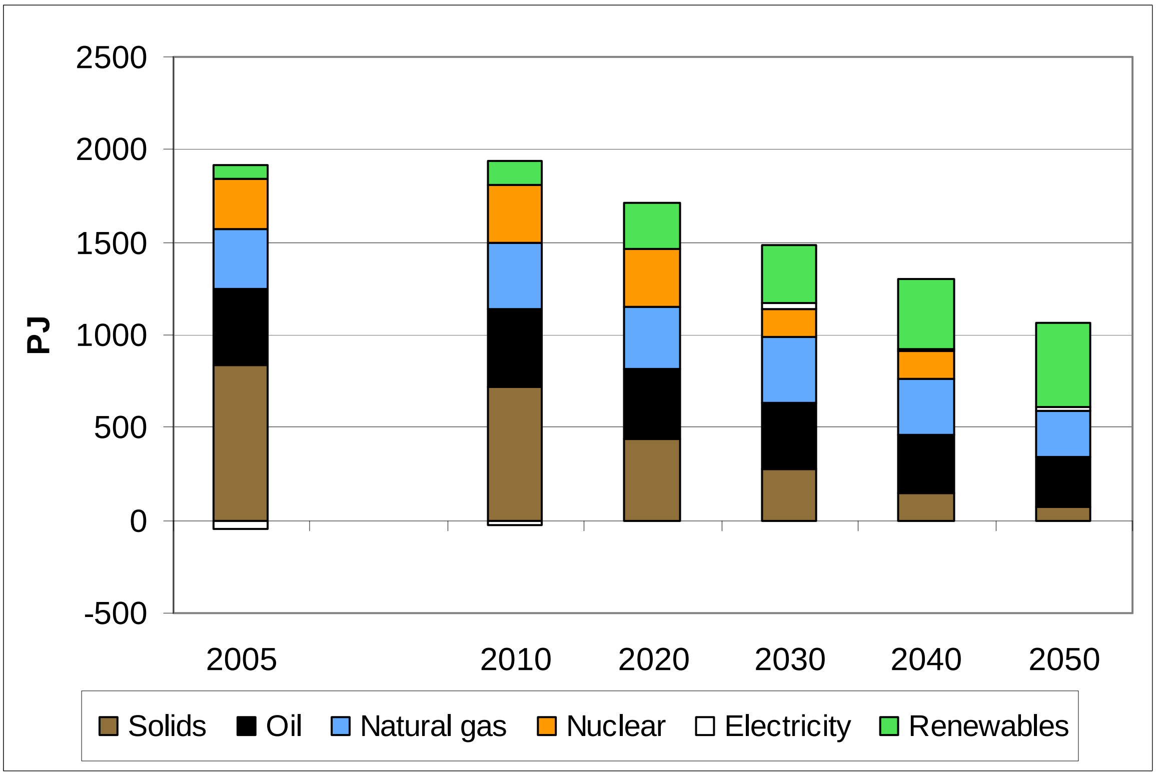
Figure 28: Comparison of primary energy supply in different alternative scenarios (in PJ)



Sources: DG TREN 2006, own calculations.

Composition of primary energy supply also changes drastically in the *Slow Progress* scenario (see Figure 29). Nuclear power is completely phased out and coal is reduced significantly. In 2050 only 9% of the amount of coal consumed in 2005 is used and coal's share in primary energy supply decreases from 45% to 7%. The contribution of renewable energy sources to primary energy supply in 2050 is more than 5 times higher than in 2005. By 2050 42% of primary energy supply is based on renewable energy forms (including electricity imports from renewable sources), up from 4% in 2005. Oil demand in 2050 is 34% below today's demand while natural gas use is down 25%.

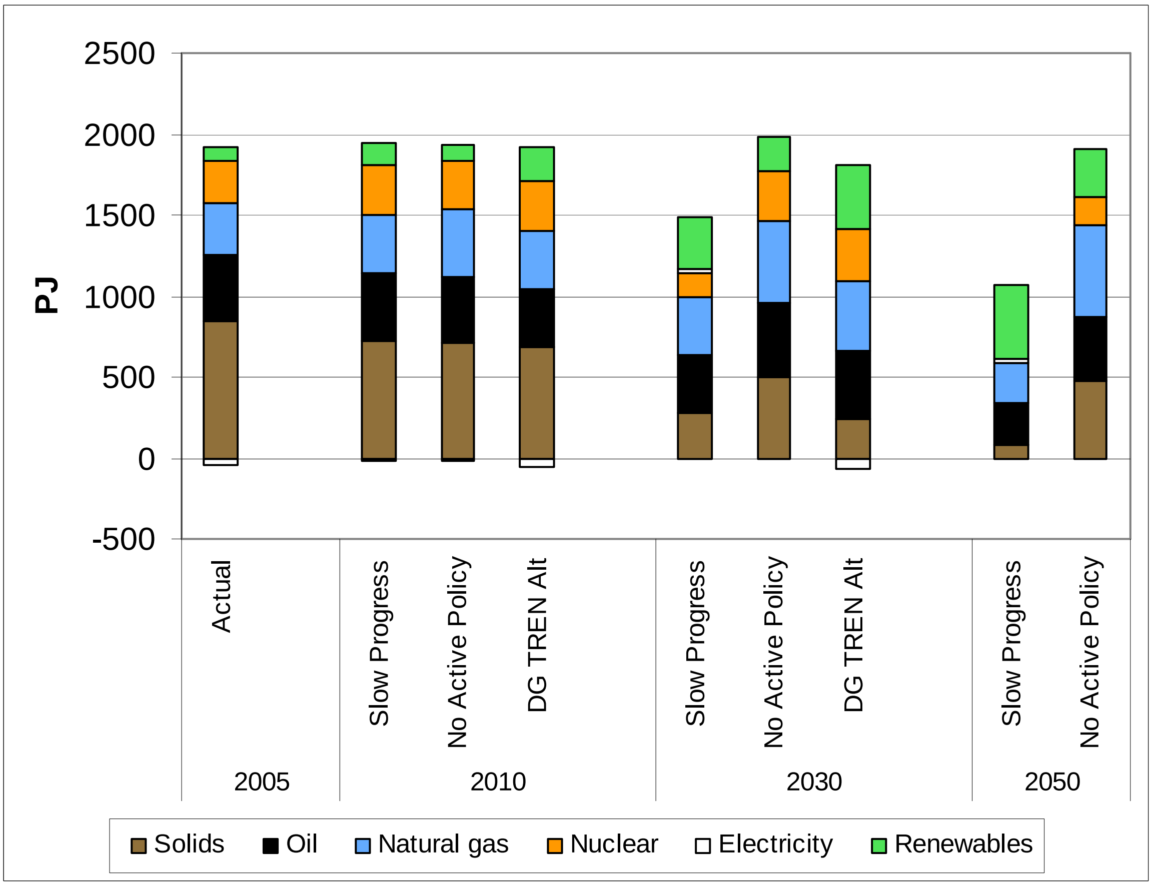
Figure 29: Sources of primary energy supply in the *Slow Progress* scenario (in PJ)



Sources: DG TREN 2008, own calculations.

Figure 30 compares primary energy supply sources in the *Slow Progress* scenario with those of the *No Active Policy* scenario described above and the alternative scenario of DG TREN (2008). As is to be expected, the *No Active Policy* scenario has higher primary energy supply and a lower contribution of renewable energy sources than the *Slow Progress* scenario. Renewable energy supply in 2030 is lower in the *Slow Progress* scenario compared to DG TREN's alternative scenario due to the different assumptions regarding renewable energy potential and the pace of its exploitation. Nuclear energy supply is also lower, apparently due to different opinions on the value of nuclear energy in an alternative energy scenario.

Figure 30: Comparison of primary energy supply by sources today and in different alternative and reference scenarios (in PJ)

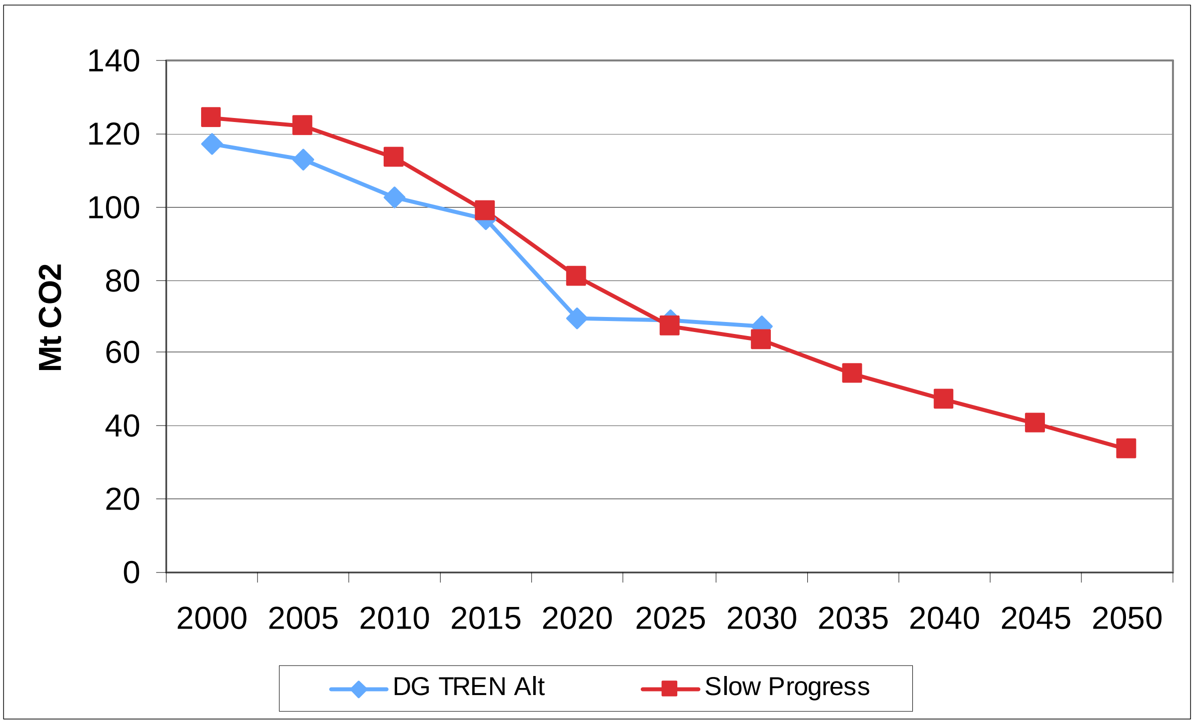


Sources: DG TREN 2006, DG TREN 2008, own calculations.

3.4.5 CO_2 emissions of the energy sector

Figure 31 shows energy-related CO_2 emissions of the *Slow Progress* scenario as well as the alternative scenario of DG TREN (2006). Emissions in the *Slow Progress* scenario decline relatively steadily throughout the observed period despite the complete phase-out of nuclear energy use after 2045. Between 2005 and 2050 CO_2 emissions go down by 72%, from 124 Mt to 34 Mt. CO_2 emissions in the DG TREN scenario develop similarly until 2030.

Figure 31: Comparison of energy-related CO_2 emission (in Mt) in different alternative scenarios

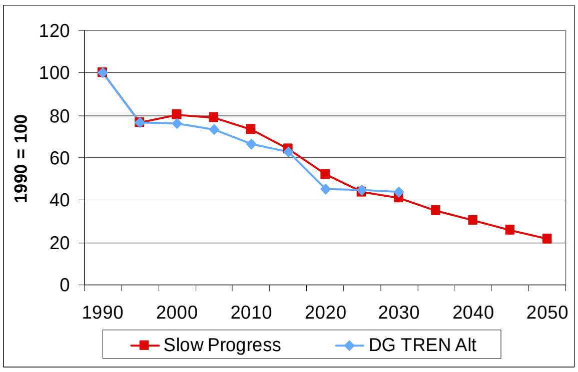


Sources: DG TREN 2006, own calculations.

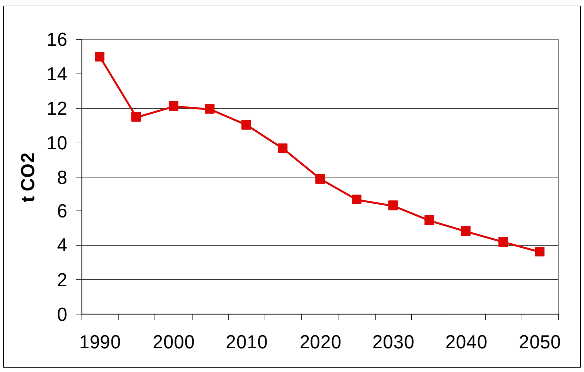
Figure 32a shows the development of CO_2 emissions in the *Slow Progress* scenario and the alternative scenario of DG TREN relative to 1990 emissions. Relative to 1990, emissions in the *Slow Progress* scenario are reduced by 78% in the year 2050. This corresponds to a drop of annual per capita emissions from 15 tons in 1990 (12 tons in 2005) to just over 4 tons in 2050. Further measures are needed to reach or at least come closer to the maximum of 2 tons of greenhouse gas emissions per capita in 2050 believed to be necessary to prevent the worst consequences of climate change.

Figures 32a, b: Comparison of development of CO_2 emissions (indexed, 1990 = 100%) in different alternative scenarios [a] and annual per capita CO_2 emissions (in t) in the *Slow Progress* scenario [b]

a



b



Sources: DG TREN 2006, own calculations.

3.5 Innovative Approach scenario

3.5.1 Major Assumptions

While climate protection in the *Slow Progress* scenario is a significant improvement over the *No Active Policy* scenario, per capita CO_2 emissions are still considerably above the per capita global average value that is believed to have to be reached by 2050 to prevent the worst consequences of climate change. As a consequence, a second alternative scenario has been developed for this report. This more ambitious alternative scenario is called the *Innovative Approach* scenario and it leads the way towards realizing a sustainable, low-carbon Czech energy system.

As the name of the scenario suggests, it is characterized by several innovative elements that help to more than half CO_2 emissions in 2050 compared to the *Slow Progress* scenario. The following are the major assumptions of the *Innovative Approach* scenario:

- No new nuclear power plants will be built in the Czech Republic. This avoids increasing the risks and problems associated with nuclear power and it also takes into account the flexibility of the electricity supply structure needed in a high-renewable energy system.

- As the risk of incidences at nuclear power plants can be expected to increase with the ageing of the plants, we assume that both nuclear plants currently in operation will be decommissioned once they reach an age of about 40 years. This means that the old nuclear power plant Dukovany will be decommissioned by 2030 (as was originally planned) while the newer plant Temelín will be in operation until 2045.

- From 2030 on the Czech Republic will start importing electricity from renewable energy sources, mostly from solar thermal power plants in North Africa.

While these assumptions are identical to the *Slow Progress* scenario[23], the following assumptions are different:

- Total final energy demand is further reduced by 20% compared to final energy demand in the *Slow Progress* scenario. These further reductions in final energy demand are assumed to be achievable though prompt implementation of several different, focused and ambitious political efficiency support measures (see chapter 3.5.2 and chapter 4.1).

- Carbon Capture & Storage (CCS) is assumed to be utilized in a 400 MW biomass power plant as well as in a handful of medium- and large-sized industrial plants (mostly in the iron and steel industry). However, our assumptions regarding this technology are comparatively conservative as we assume that CCS will be ready for commercial use only from 2030 on and the volume of CO_2 emissions captured and stored in the *Innovative Approach* scenario does not exceed 6 Mt per year. Cumulative storage requirements until 2050 are around 100 Mt CO_2 and are thus well below the estimated geological storage potential in the Czech Republic of 3,300 Mt CO_2 (Hladík et al 2009).

[23] However, in the *Innovative Approach* scenario somewhat more electricity from renewable sources is imported from 2030 on compared to the *Slow Progress* scenario.

- The transport sector is further decarbonized through an increased use of biofuels and especially through a much stronger push for electric vehicles using electricity from renewable sources.

- It is assumed that from 2030 on considerable amounts of biogas will be imported by the Czech Republic from abroad, rising to about 20% of all gas imports by 2045.[24]

Apart from achieving very low CO_2 emissions, the *Innovative Approach* scenario has an additional advantage over both other scenarios described in this report: Only in the *Innovative Approach* scenario can the share of imported energy be reduced in 2050 compared to today's share, from 43% in 2005 to 41% in 2050. In the *No Active Policy* scenario this share rises dramatically to 79% in 2050.[25]

3.5.2 Final energy demand

Total final energy demand in the *Innovative Approach* scenario is further reduced compared to the *Slow Progress* scenario (see Figure 33). More ambitious energy efficiency policies will have to be enacted in all sectors of the economy to realize this potential and also some lifestyle changes, especially in mobility (see below) may be needed. In order to be able to make such dramatic progress in energy efficiency, a number of different types of efficiency measures need to be implemented as soon as possible. It is critical to use various different types and combine them in such a way that they can benefit from one another. For instance, well thought out, large-scale information campaigns are helpful to raise awareness in the public about the need to increase energy efficiency. This awareness as well as monetary incentives can help raise public support for measures like ambitious and evolving efficiency standards in all sectors. More government support for R&D in the area of energy efficiency in turn helps to make it easier for the economic actors to achieve drastic medium to long term improvements in energy efficiency standards.

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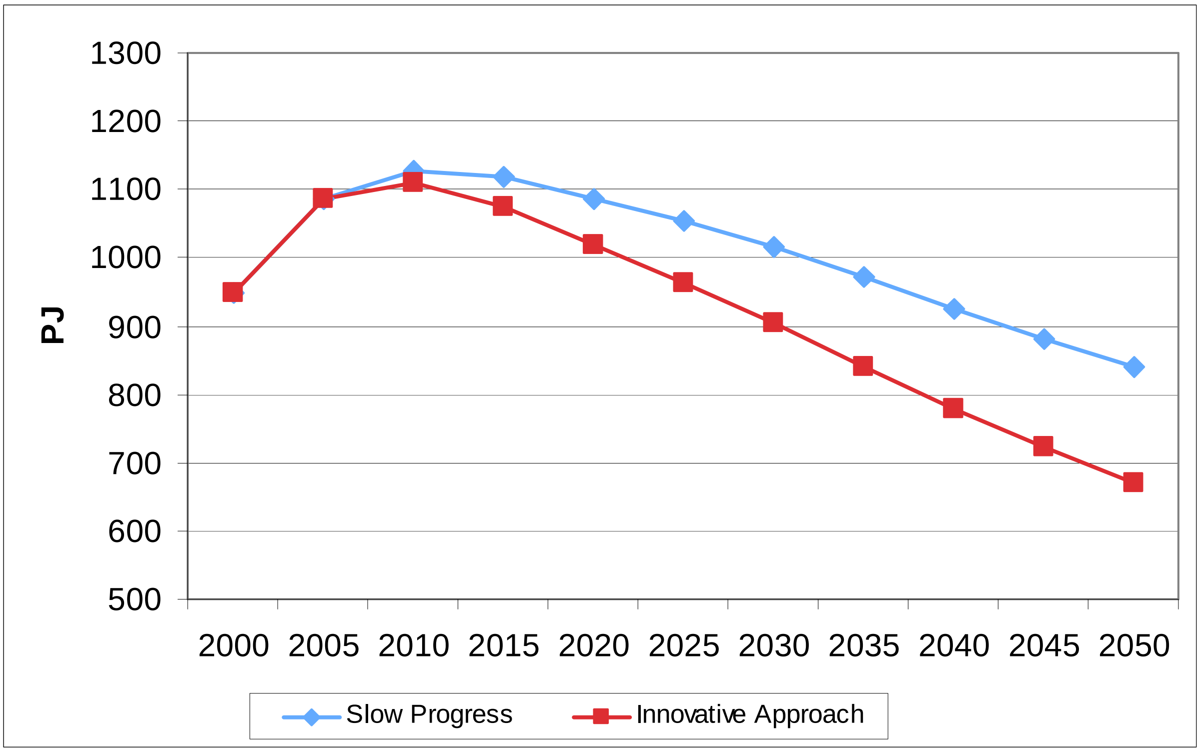
[24] In the following figures and explanations, this share of biogas will not be mentioned separately but will implicitly be included when it is referred to as "natural gas" or "gas" in the *Innovative Approach* scenario.

[25] The shares given here are based on calculations that treat nuclear fuel as an imported energy source. While the Czech Republic produces uranium from domestic sources, it relies on foreign countries like Russia and France for conversion and enrichment of uranium. Domestic uranium production is expected to decline in the near future (IAEA 2003). See the overviews in chapter 3.6 for the corresponding figures treating nuclear energy as a domestic energy source.

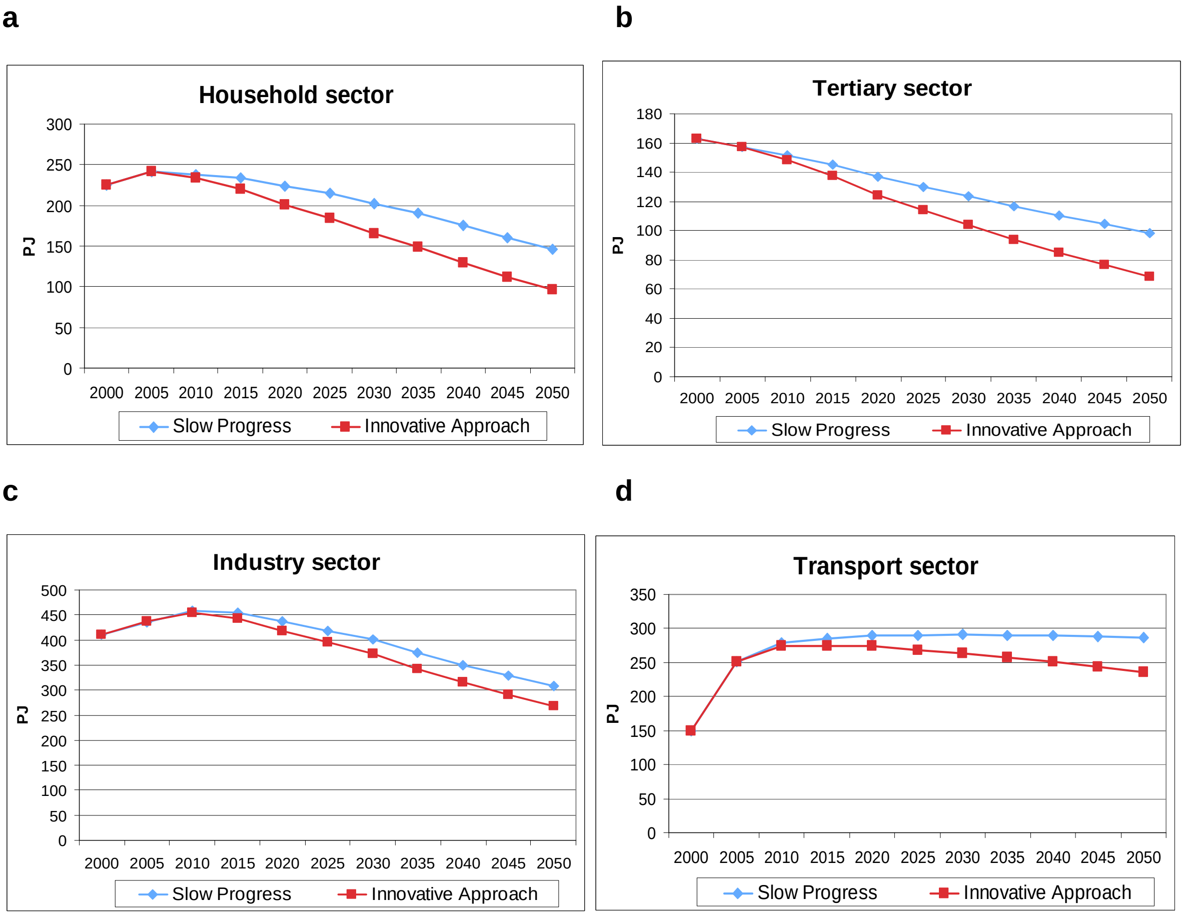
Figure 33: Comparison of total final energy demand (in PJ) in the *Slow Progress* scenario and the *Innovative Approach* scenario



Sources: SEVEn 2008, own calculations.

Total final energy demand in 2050 in the *Innovative Approach* scenario is 20% below demand in the *Slow Progress* scenario. However, energy demand is not reduced by the same factor in all four sectors. Instead, based on analysis of existing alternative energy scenarios and bottom-up studies (see above) as well as based on internal expertise, we've identified different potential for further demand reductions in each sector (see Figures 34a-d).

Figures 34a-d**:** Comparison of final energy demand (in PJ) in the different sectors in the *Slow Progress* scenario and the *Innovative Approach* scenario



Sources: SEVEn 2008, own calculations.

In relative terms we see the largest additional savings potential in the household sector (a reduction of 34% over the *Slow Progress* scenario in 2050, see Figure 34a). These additional savings lead to a decrease in final energy demand by 60% compared to today's demand. Such a reduction has been shown to be technically feasible in the Czech Republic's household sector until 2050 (Šafařík / Klusák 2007a)[26]. The large energy savings potentials in the household sector can be realized mostly through well-financed programmes to improve insulation of existing buildings and though strict and continuously tightening standards for new buildings. More efficient generation and use of warm water and heat for cooking as well as more efficient household appliances are also needed. We assume that this efficiency potential is realized in the *Innovative Approach* scenario through legislation mandating the use of certain energy efficient technologies and setting stringent and dynamically changing energy efficiency standards for household appliances. For these and further measures in the household sector that need to be enacted in the *Innovative Approach* scenario, see chapter 4.1.2.

[26] The 60% reduction in final energy demand by 2050 that this study finds to be technically feasible includes the use of solar thermal heat. However, the use of solar thermal heat should rather be considered a change in energy source and is thus not included in our model as a reduction in final energy demand. We still use the assumption of a 60% reduction in final energy demand by 2050 compared to 2005 as only a small part of the cited study's energy savings come from the use of solar thermal energy. In addition, internal studies by

In the tertiary sector final energy demand in 2050 is another 30% below demand in the *Slow Progress* scenario (see Figure 34b) and 50% below the *No Active Policy* scenario. In the alternative scenario of the European Union's DG TREN study, final energy demand in the tertiary sector is already 50% below baseline demand in 2030. A detailed bottom-up study of the Czech Republic's service sector (Šafařík / Klusák 2007b) and estimates from the Wuppertal Institute both indicate that the further energy demand reductions assumed here are indeed realizable. As in the household sector, by far the most important measure to achieve the saving potential is to drastically improve the insulation of existing and new buildings over the next four decades. More efficient use of electricity (e.g. for cooling and office appliances) also constitutes a significant part of the saving potential in this sector. For these and further measures in the tertiary sector that need to be enacted in the *Innovative Approach* scenario, see chapters 4.1.1 and 4.1.3.

In the industry sector we assume additional final energy savings compared to the *Slow Progress* scenario of 13% in 2050 (see Figure 34c). Compared to the other sectors the additional energy efficiency gains assumed here are more modest, as existing alternative scenarios and bottom-up studies suggest that the final energy demand reductions achieved in *Scenario E* compared to *Scenario C* of the Independent Energy Commission's report are already quite ambitious at 42% in 2050. However, various studies suggest that in most industrial branches potential technical energy savings are around 50% and up to 75% in some others (Ecofys 2006 and literature cited therein).

It can therefore be assumed that today's final energy demand in the industry sector is about 50% higher than it would be if only the most efficient available technology was used. We assume that in a baseline scenario this share will remain unchanged over time and thus conclude that final energy demand in the industry sector in the *Innovative Approach* scenario could be 50% below demand in the *No Active Policy* scenario. This leads to the aforementioned 13% reduction over the *Slow Progress* scenario in 2050. We assume that this progress in industrial efficiency is achieved through different and very ambitious political measures. Such measured include enacting stringent and dynamically changing efficiency standards, the introduction of white certificates and the institutionalization of energy efficiency, for example by setting up regional "energy centres" that provide information and advice as well as loans to local companies for energy efficiency investments. For these and further measures in the industry sector that need to be enacted in the *Innovative Approach* scenario, see chapter 4.1.1.

Finally, in the transport sector we assume additional energy savings over the *Slow Progress* scenario of 18% in 2050 (see Figure 34d). Available studies suggest that the efficiency gains foreseen in the Independent Energy Commission's *Scenario E* over its *Scenario C* are already very ambitious. Therefore we have assumed that only a small part (about 5 percentage points) of the additional savings are due to efficiency improvements in conventional technologies. The majority of savings (about 8 percentage points) are the result of a significant increase in the share of electricity in individual transportation.[27] Another 5 percentage

the Wuppertal Institute show that the refurbishment rates assumed in the study could be exceeded in reality, thus possibly enabling energy savings that are even higher than 60%.

27 Engines powered by electricity are much more efficient than combustion engines (not accounting for losses in electricity generation) and thus lead to lower final energy demand. We assume that in 2050 an electrically

points would come from shifts in modal split (see chapter 4.1.4), leading to less individual motor car transport. We assume that in the *Innovative Approach* scenario a multitude of different policy measures will be enacted to achieve these additional energy savings. In the medium and long run, enacting tightening emission limits for new vehicles and increasing the attractiveness of public transportation compared to individual transportation could be the most central policy measures. In the coming years considerable support for R&D in the field of electric vehicles is needed, but this should be coordinated on a European or an even broader international level. For these and further measures in the transport sector that need to be enacted in the *Innovative Approach* scenario, see chapter 4.1.4.

3.5.3 Electricity consumption and electricity supply

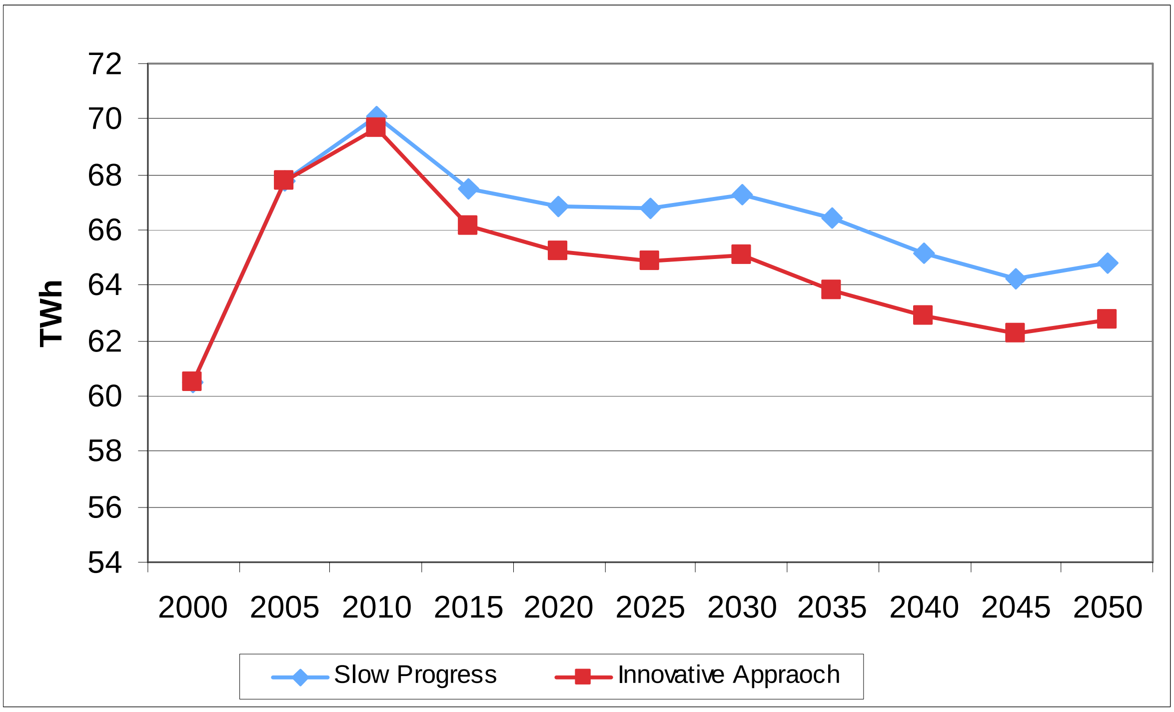
3.5.3.1 Electricity consumption

As a consequence of the additional savings in final energy demand assumed in all sectors, electricity consumption in the *Innovative Approach* scenario is lower than in the *Slow Progress* scenario (see Figure 35). However, the reduction in electricity demand (-3% in 2050) is much less pronounced than the reduction in final energy demand (-20%). There are two main reasons for this:

- We assume that there is more potential to reduce heat demand (mainly by improvements in insulation) than electricity demand, not just in absolute terms but also in relative terms.
- A large part of the electricity that is saved compared to the *Slow Progress* scenario is used in the transportation sector instead in order to significantly decrease oil consumption.

powered vehicle will on average be twice as efficient as a comparable vehicle powered by a combustion engine.

Figure 35: Comparison of electricity consumption in the *Slow Progress* scenario and the *Alternative Approach* scenario (in TWh)

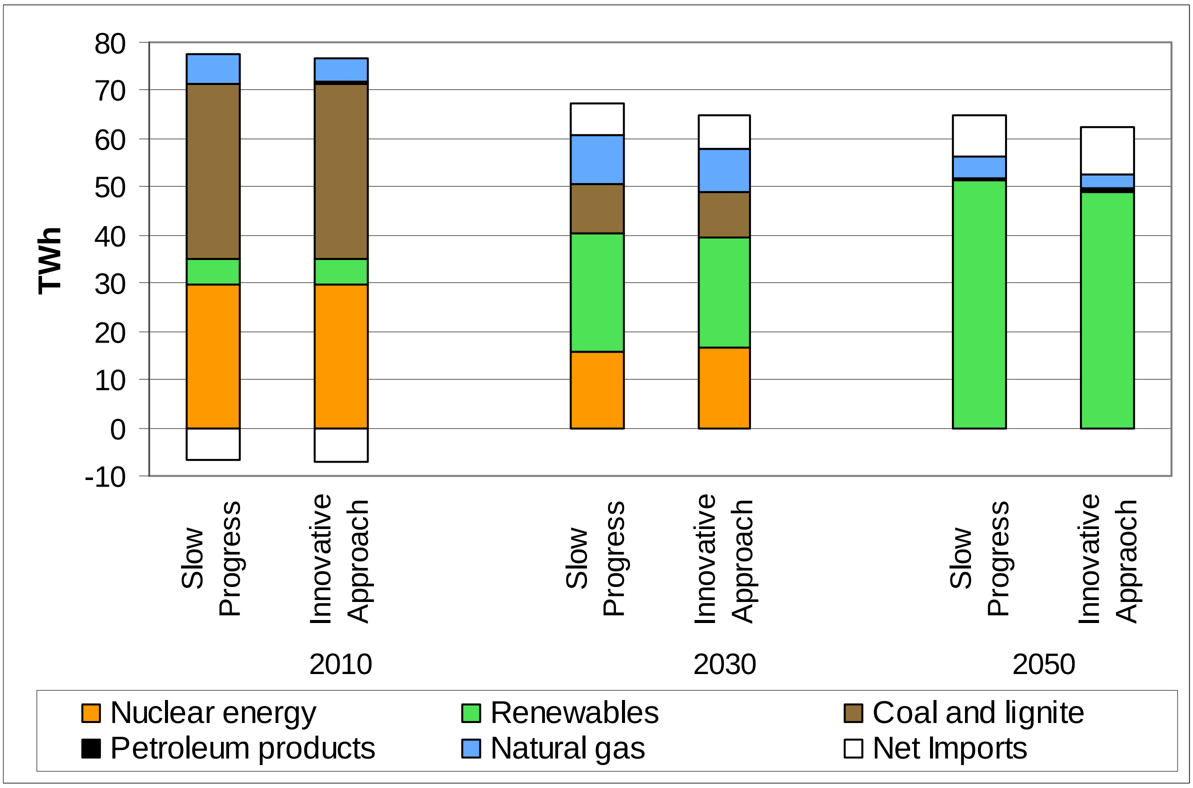


Sources: SEVEn 2008, own calculations.

3.5.3.2 Electricity production

Figure 36 shows that not only the amount of gross electricity production but also its structure is very similar to the *Slow Progress* scenario. In the *Innovative Approach* scenario in 2050 the share of natural gas in electricity generation is reduced from 7% to 5%. The share of electricity from domestic renewable sources is reduced slightly by about 1 percentage point (from 79.5% to 78.6%) which is due to more of the domestic biomass potential being used for other purposes, mainly for meeting a higher demand for biofuels. At the same time the amount of electricity imported from renewable sources (especially from solar thermal power plants) in 2050 is increased from 8.3 TWh in the *Slow Progress* scenario to 10 TWh in the *Innovative Approach* scenario.

Figure 36: Comparison of gross electricity production by source and net electricity imports in the *Slow Progress* scenario and the *Alternative Approach* scenario (in TWh)



Source: Own calculations.

Table 3 shows the average efficiencies of electricity production of newly-built and of all existing non-CHP power plants as well as average efficiencies of electricity and heat production of newly-built and of all existing CHP power plants.[28] The figures are similar to the *Slow Progress* scenario as the energy systems of both scenarios are similar. A notable difference is the assumed efficiency of non-CHP biomass power plants built between 2025 and 2030. Their efficiency is assumed to be 25% and is thus 8 percentage points below the assumed efficiency of such plants in the *Slow Progress* scenario. This reduction in efficiency is explained by the use of CCS technology in the only non-CHP biomass power plant (400 MW) built between 2025 and 2030. The use of this technology leads to a reduction in power plant efficiency. We have assumed that around 2030 efficiency of a CCS biomass power plant will be 8 percentage points below a non-CCS biomass power plant.

[28] In Table 3 dashes instead of figures indicate that no new power plants of the respective type are built or in operation at that time.

Table 3: Average efficiencies of electricity (and heat) production in different types of non-CHP and CHP power plants in the *Innovative Approach* scenario

Newly-built non-CHP plants

	2005-2010	**2015-2020**	**2025-2030**	**2035-2040**	**2045-2050**
coal	-	-	-	-	-
gas	-	-	-	-	-
biomass	31%	33%	27%	-	-

All existing non-CHP plants

	2010	**2020**	**2030**	**2040**	**2050**
coal	34%	34%	34%	40%	40%
gas	34%	37%	39%	-	-
biomass	29%	30%	25%	25%	25%

Newly-built CHP plants

	2005-2010	**2015-2020**	**2025-2030**	**2035-2040**	**2045-2050**
coal	75%	78%	79%	-	-
gas	82%	84%	87%	89%	-
biomass	80%	81%	83%	84%	-

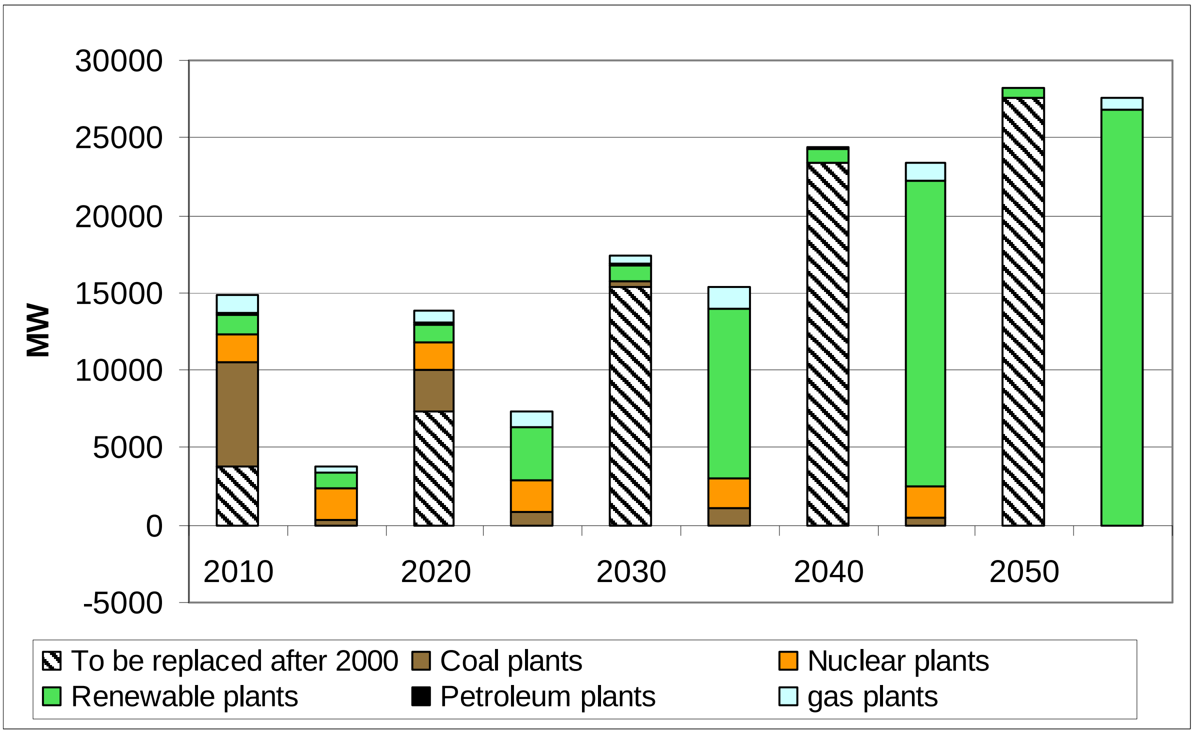
All existing CHP plants

	2010	**2020**	**2030**	**2040**	**2050**
coal	69%	72%	77%	77%	77%
gas	80%	82%	83%	83%	83%
biomass	75%	79%	80%	81%	81%

Sources: IEA 2008a, own calculations.

The structure of power generation in the *Slow Progress* scenario and the *Innovative Approach* scenario is very similar. Figure 37 shows the capacity structure and the changes since the year 2000 in the *Innovative Approach* scenario.

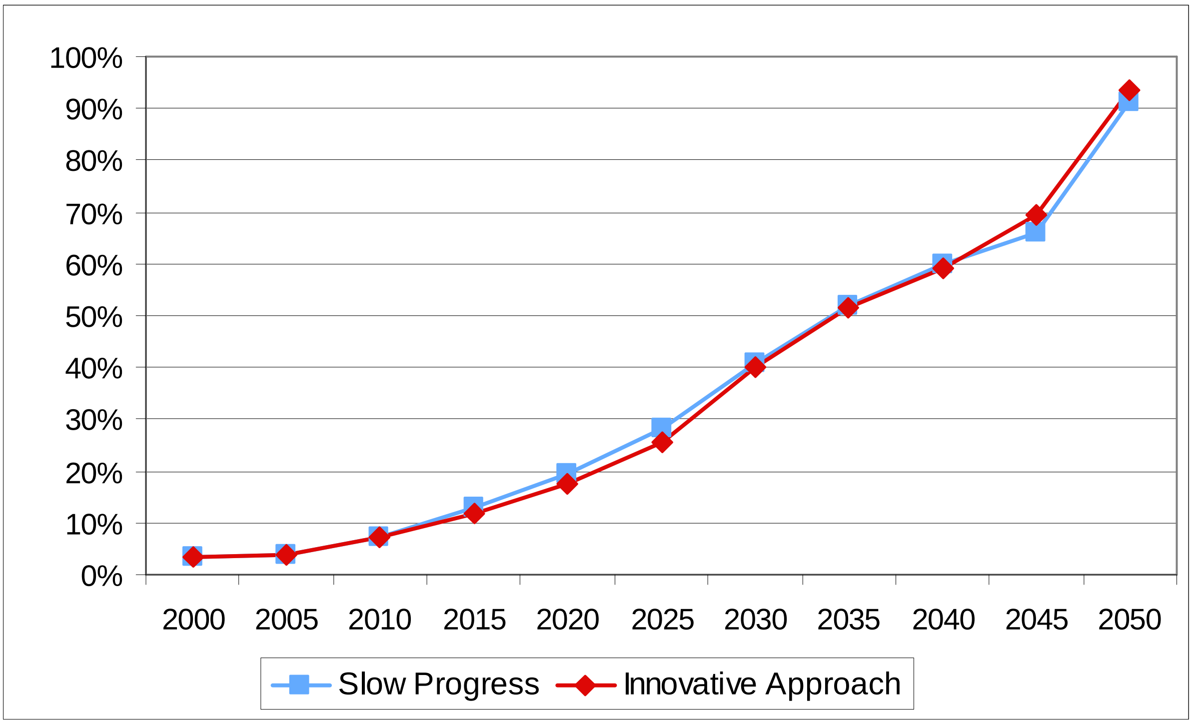
Figure 37: Power plant capacity in the *Innovative Approach* scenario (in MW, including CHP) with separate depiction of capacity added after the year 2000



Source: Own calculations.

Figure 38 shows that the share of renewable energy in domestic electricity production is similar in the *Slow Progress* scenario and the *Innovative Approach* scenario. However, by 2050 the share is even higher in the latter scenario at just under 94% compared to 91% in the *Slow Progress* scenario.

Figure 38: Comparison of share of renewable energy in domestic electricity generation in the *Slow Progress* scenario and the *Innovative Approach* scenario (in %)



Source: Own calculations.

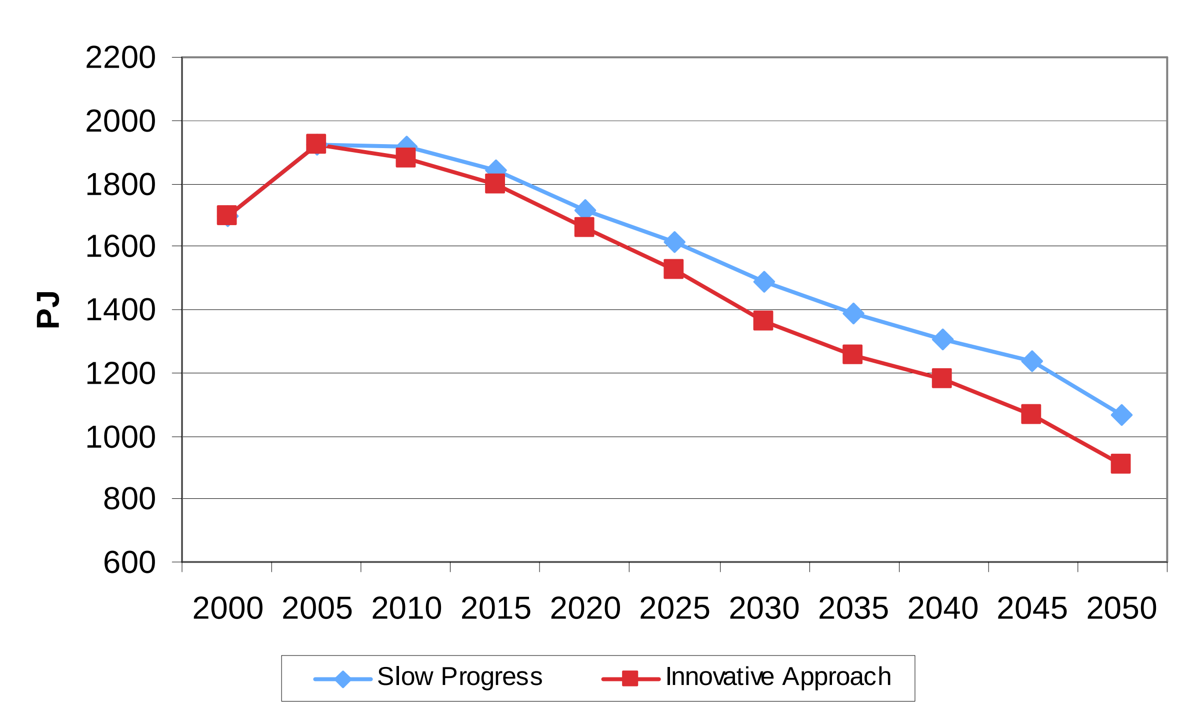
The share of the fluctuating renewable energy sources wind and solar increases over the observed period and reaches 37.5% of total electricity supply in 2050. We assume that appropriate measures will be taken in time to ensure that a reliable electricity supply will be guaranteed despite this increase in fluctuating electricity sources. Such measures include extending and upgrading the domestic and European electricity grid in order to enable more trade in electricity between different regions and the broad use of demand side management to better align electricity supply and demand. Technical storage solutions like compressed air reservoirs, pump storage and possibly also hydrogen may be needed to some extent as well.

3.5.4 Primary energy supply

Figure 39 shows that primary energy supply in the *Innovative Approach* scenario is lower than in the *Slow Progress* scenario (by 15% in 2050). However, as relatively more electricity is used in final energy demand in the *Innovative Approach* scenario, primary energy demand does not decline as much as final energy demand.[29]

[29] In 2050 22% of the generated electricity comes from biomass. Transformation losses from this source of electricity generation are the main reason why electricity is still more primary energy intensive than other sources of final energy demand.

Figure 39: Comparison of primary energy supply in *Slow Progress* scenario and *Innovative Approach* scenario (in PJ)

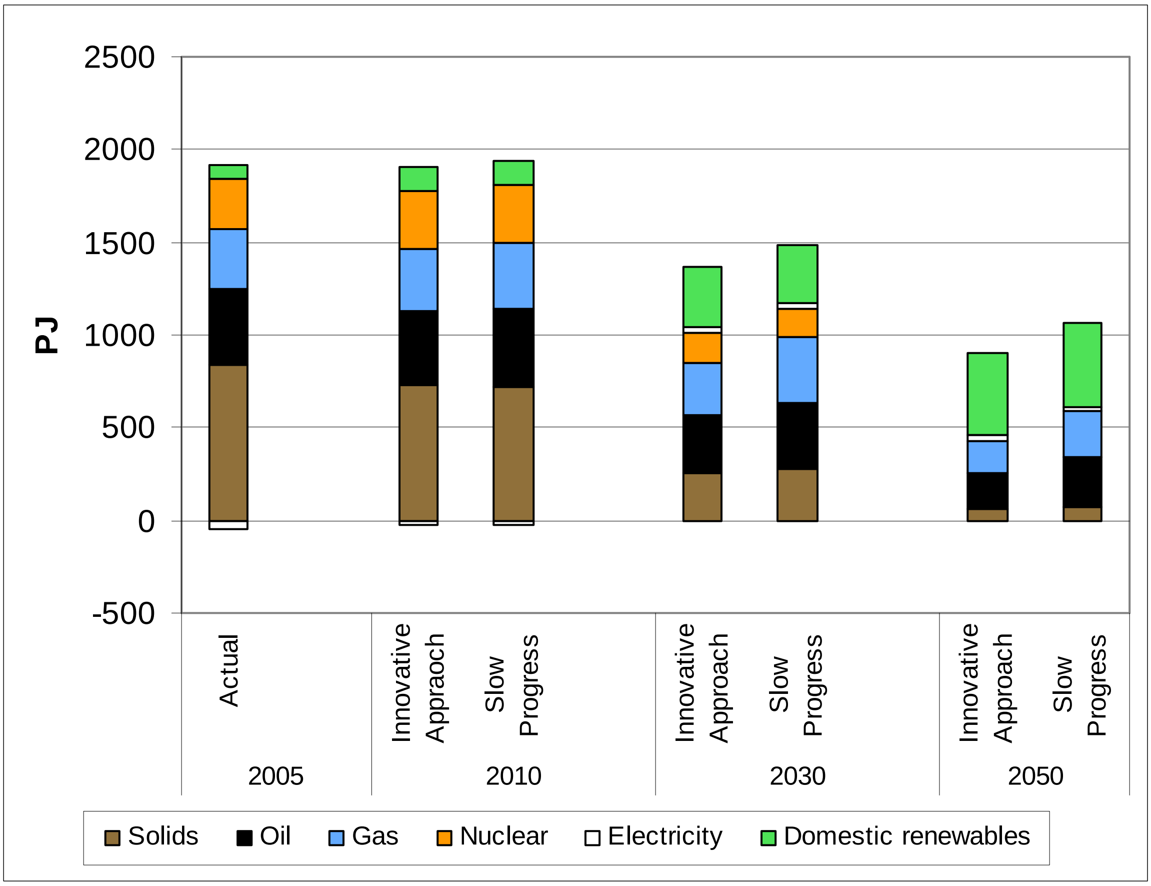


Source: Own calculations.

Figure 40 shows primary energy supply by sources in both the *Innovative Approach* scenario and the *Slow Progress* scenario. While primary energy supply from domestic[30] renewable sources is the same in both scenarios, reliance on coal (22%) and especially on oil (27%) and gas (31%) is further reduced in the *Innovative Approach* scenario. Oil demand reductions are mostly a result of the significant change in the transport sector's energy mix, increasing the share of biofuels and electricity while decreasing the share of oil. Gas demand is reduced in all sectors as a result of higher efficiency and a switch-over to renewable energy sources (e. g. solar thermal energy in the household sector). In relative terms coal use is not reduced as much, as by the end of the observed period it is assumed to be used mainly in industrial processes with limited potential for energy source substitution.

30 As electricity imports from renewable energy sources are increased and a rising share of gas supply comes from biogas imports, the total contribution (including non-domestic sources) of renewable energy is actually higher in the *Innovative Approach* scenario than in the *Slow Progress* scenario.

Figure 40: Comparison of primary energy supply by sources today and in the *Slow Progress* scenario and *Innovative Approach* scenario until 2050 (in PJ)



Sources: DG TREN 2008, own calculations.

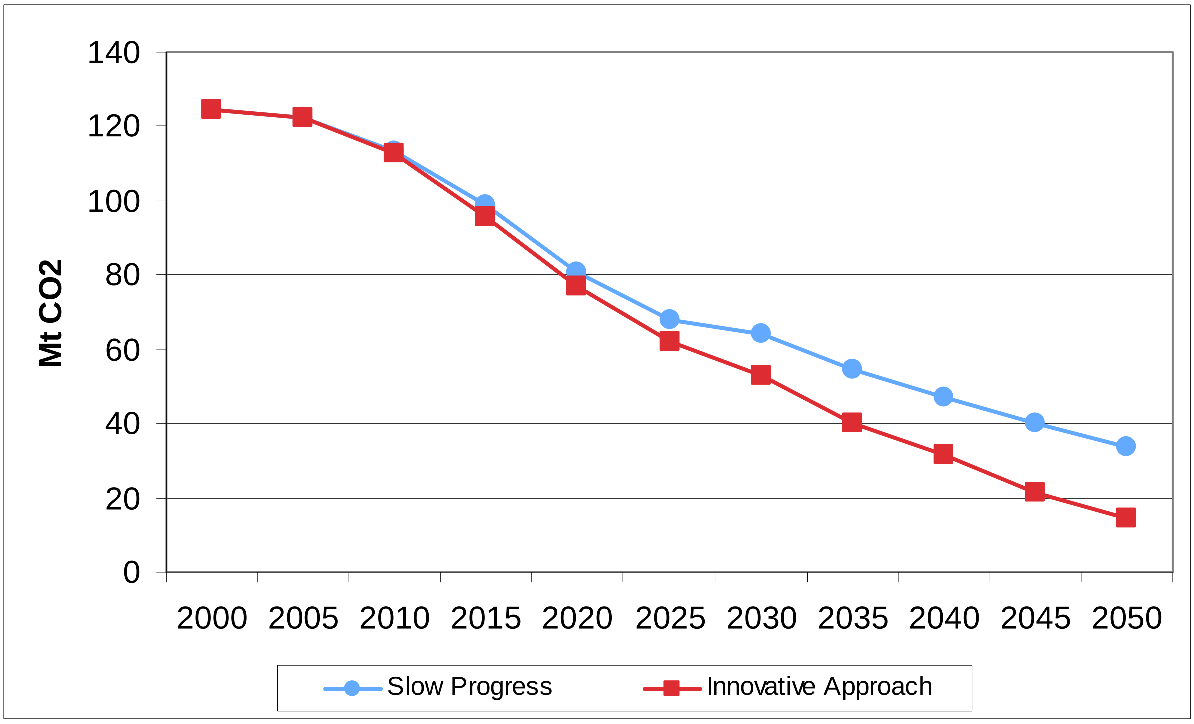
3.5.5 CO_2 emissions of the energy sector

Figure 41 shows energy-related CO_2 emissions in the *Innovative Approach* scenario and the *Slow Progress* scenario. In the *Innovative Approach* scenario, CO_2 emissions are reduced more aggressively and amount to less than half of the CO_2 emissions in the *Slow Progress* scenario in 2050 (15 Mt compared to 34 Mt). The following six changes in the energy system of the *Innovative Approach* scenario compared to the energy system of the *Slow Progress* scenario explain this significant further reduction of CO_2 emissions:

- Lower final energy demand leading to lower fossil fuel use
- Substantial changes in the energy mix of the transport sector (including modal shift)
- Full utilization of domestic biomass potential
- Increase in imports of electricity from renewable sources
- Imports of biogas
- Utilization of Carbon Capture and Storage (CCS) technology

Many of these changes (widespread use of electric cars, imports of electricity from renewable sources, biogas imports and CCS utilization) are implemented only in the second half of the observed period. This explains why CO_2 emissions in the *Innovative Approach* scenario start to deviate significantly from CO_2 emissions in the *Slow Progress* scenario only after 2025. CO_2 emissions in the *Innovative Approach* scenario are 88% lower in 2050 than they were in 2005.

Figure 41: Comparison of energy-related CO_2 emission (in Mt) in the *Slow Progress* scenario and the *Innovative Approach* scenario

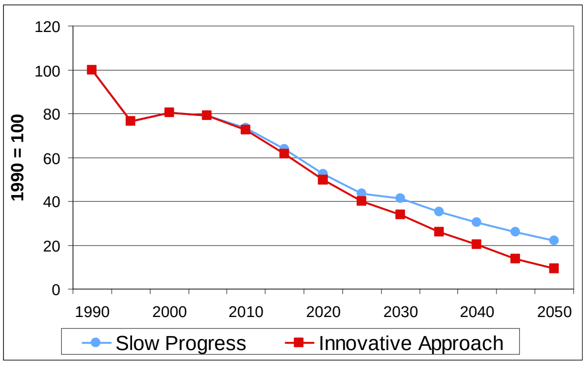


Source: Own calculations.

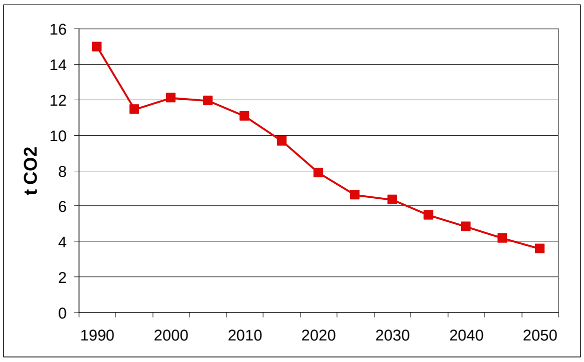
Figure 42a shows the development of CO_2 emissions in the *Innovative Approach* scenario and the *Slow Progress* scenario relative to 1990 emissions. Relative to 1990, emissions in the *Innovative Approach* scenario are reduced by 91% in the year 2050. This corresponds to a drop of annual per capita emissions from 15 tons in 1990 (12 tons in 2005) to 1.5 tons in 2050 (see Figure 42b).

Figures 42a, b: Comparison of development of CO_2 emissions (indexed, 1990 = 100%) in the *Innovative Approach* scenario and the *Slow Progress* scenario [a] and annual per capita CO_2 emissions (in t) in the *Innovative Approach* scenario [b]

a



b



Source: Own calculations.

Provided similar reductions in non-energy and non-CO_2 greenhouse gases can be achieved, the *Innovative Approach* scenario allows for the goal of 2 tons of CO_2-equivalent emissions per capita by 2050 to be achieved.

3.6 Summaries of scenarios[31]

3.6.1 No Active Policy scenario

	2005	2010	2015	2020	2025	2030	2040	2050
Primary production (PJ)	**1,104**	**961**	**803**	**641**	**557**	**582**	**383**	**397**
Solids	985	841	665	489	369	217	108	84
Oil	24	13	13	0	0	0	0	0
Natural gas	6	8	8	8	8	8	8	8
Renewable energy sources	89	99	118	144	181	206	267	305
Hydro	8	8	8	8	8	8	9	9
Biomass and waste	81	89	105	128	160	179	225	248
Wind	0	2	4	6	7	8	10	12
Solar	0	0	0	1	4	8	16	25
Geothermal	0	0	0	0	1	3	7	12
Net imports (PJ)	**789**	**956**	**1,149**	**1,311**	**1,420**	**1,399**	**1,602**	**1,513**
Solids	-146	-126	-8	101	162	133	343	388
Oil	398	385	418	447	460	456	435	402
Natural gas and other gases	315	411	452	461	478	490	503	553
of which biogas	0	0	0	0	0	0	0	0
Nuclear	267	302	302	302	320	320	320	170
Electricity	-45	-16	-16	0	0	0	0	0
Total primary energy supply (PJ)	**1,893**	**1,917**	**1,951**	**1,952**	**1,977**	**1,981**	**1,985**	**1,910**
Solids	839	715	657	590	531	502	452	473
Oil	422	397	431	447	460	456	435	402
Natural gas and other gases	321	418	460	468	485	498	510	560
of which biogas	0	0	0	0	0	0	0	0
Nuclear	267	302	302	302	320	320	320	170
Electricity	-45	-16	-16	0	0	0	0	0
Renewable energy sources	89	99	118	144	181	206	267	305
Total primary energy supply (%)	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Solids	44.3	37.3	33.6	30.2	26.9	25.3	22.8	24.7
Oil	22.3	20.7	22.1	22.9	23.3	23.0	21.9	21.1
Natural gas and other gases	17.0	21.8	23.6	24.0	24.5	25.1	25.7	29.3
Nuclear	14.1	15.8	15.5	15.5	16.2	16.2	16.1	8.9
Renewable energy forms	4.7	5.2	6.0	7.4	9.1	10.4	13.5	16.0

[31] Data for the year 2005 depicted in this table and used for the model calculations may differ from data and figures for the same year provided in chapter 2 as different sources were used. The main source for the 2005 data of this table is DG TREN (2008). Also note that in these tables fuel for nuclear power plants is treated as an imported energy source.

	2005	2010	2015	2020	2025	2030	2040	2050
Domestic electricity generation (TWh_e)	**78.3**	**75.5**	**76.8**	**75.3**	**77.3**	**80.3**	**84.6**	**90.6**
Nuclear	27.3	28.8	28.8	28.8	30.4	30.4	30.4	17.0
Hydro, wind and solar	2.4	2.9	3.4	4.2	5.3	6.7	9.8	12.8
Thermal (fossil + biomass and waste)	48.6	43.9	44.6	42.2	41.6	43.2	44.4	60.8
Energy branch consumption (PJ)	**78.4**	**91.9**	**92.2**	**95.5**	**99.8**	**104.6**	**112.9**	**121.3**
Non-energy use (PJ)	**101.2**	**119.1**	**134.0**	**150.2**	**162.9**	**171.8**	**192.4**	**204.9**
Final energy demand - by sector (PJ)	**1,085**	**1,153**	**1,204**	**1,242**	**1,265**	**1,272**	**1,296**	**1,293**
Industry	436	480	498	510	518	522	531	534
Residential	241	244	248	247	244	235	227	213
Tertiary	157	150	149	147	146	143	140	136
Transport	251	279	309	338	356	372	398	410
Final energy demand - by fuel (PJ)	**1,085**	**1,153**	**1,204**	**1,242**	**1,265**	**1,272**	**1,296**	**1,293**
Solids	116	115	109	100	90	79	57	37
Oil	304	329	354	371	380	378	358	331
Natural gas and other gases	286	287	300	310	320	328	347	353
Electricity	193	203	207	214	216	221	237	258
Heat (from CHP and district heating)	144	150	151	151	150	146	142	140
Biomass/waste and solar thermal	42	70	83	95	109	120	155	174
CO_2 emissions (Mt CO_2)	**122.5**	**116,0**	**113.6**	**108.8**	**104.1**	**102.3**	**97.3**	**101.7**
Electricity and steam production	69.6	61.0	56.5	50.7	45.7	44.6	41.2	49.3
of which negative emissions from CCS	0	0	0	0	0	0	0	0
Energy branch	2.0	2.2	2.2	2.2	2.2	2.2	2.4	2.5
Industry	18.7	19.9	20.5	20.6	20.4	19.8	18.2	16.6
of which negative emissions from CCS	0	0	0	0	0	0	0	0
Residential	7.6	7.5	7.3	7.1	6.7	6.3	5.9	5.5
Tertiary	6.1	5.2	5.1	4.8	4.6	4.5	4.2	4.0
Transport	18.6	20.2	22.0	23.5	24.4	24.8	25.3	24.0
CO_2 emission index (1990 = 100)	**79.1**	**74.9**	**73.3**	**70.2**	**67.2**	**66.0**	**62.9**	**65.7**

	2005	2010	2015	2020	2025	2030	2040	2050
Main energy system indicators								
Population (million)	10.2	10.3	10.3	10.3	10.2	10.1	9.8	9.4
GDP (1000 MEUR'05)	99.9	128.1	155.8	185.6	216.9	248.8	314.1	380.6
TPES/GDP (PJ/MEUR'05)	19.3	15.0	12.5	10.5	9.1	8.0	6.3	5.0
TPES/capita (TJ/inhabitant)	188.8	186.4	189.8	189.8	194.0	196.1	202.6	202.4
Carbon intensity (t CO_2/PJ of TPES)	63.4	60.3	58.0	55.5	52.4	51.3	48.6	52.7
CO_2 emissions/capita (t CO_2/inhabitant)	12.0	11.3	11.0	10.6	10.2	10.1	9.9	10.8
CO_2 emissions to GDP (t CO_2/MEUR'05)	1225.8	905.9	729.1	586.0	480.1	411.0	310.0	267.2
Import dependency (%)	43.1	49.9	58.9	67.2	71.8	70.6	80.7	79.2
Import dependency (%, nuclear domestic)	27.1	34.1	43.4	51.7	55.6	54.5	64.6	70.3
Energy intensity indicators (1990=100)								
Industry (energy on value added)	37.6	32.0	28.1	24.5	21.9	20.0	17.0	14.7
Residential (energy on private income)	50.3	39.8	33.3	27.8	23.5	19.7	15.1	11.7
Tertiary (energy on value added)	38.4	29.3	23.6	19.2	16.0	13.3	9.9	7.7
Transport (energy on GDP)	174.4	151.1	137.3	126.2	113.9	103.8	88.0	74.8
Primary energy efficiency								
Total (MEUR/PJ)	51.7	66.8	79.8	95.1	109.7	125.6	158.3	199.3
Index (2005=100)	100.0	129.2	154.4	183.9	212.1	242.9	306.0	385.3
Carbon intensity indicators								
Electricity and heat production (t CO_2/MWh)	0.49	0.44	0.40	0.37	0.33	0.32	0.29	0.32
Final energy demand (thousand t CO_2/PJ)	46.9	45.8	45.5	45.0	44.4	43.6	41.4	38.8
Industry	42.8	41.4	41.2	40.3	39.4	38.0	34.3	31.0
Residential	31.6	30.9	29.3	28.7	27.3	26.8	26.2	26.0
Tertiary	38.7	34.8	33.9	32.4	31.8	31.4	30.4	29.6
Transport	74.0	72.2	71.3	69.5	68.6	66.6	63.4	58.6
Electricity and heat generation (MW_e)								
Total capacity	15,505	15,278	15,369	14,949	15,264	15,397	16,464	17,394
Nuclear	3,760	3,760	3,760	3,760	3,760	3,760	3,760	2,000
Hydro (pumping excluded)	1,198	1,256	1,264	1,270	1,262	1,246	1,246	1,246
Wind	30	387	700	1,000	1,200	1,400	1,700	1,900
Solar	1	2	20	100	350	700	1,500	2,300
Thermal (non-nuclear)	10,516	9,873	9,624	8,819	8,691	8,291	8,258	9,948
of which cogeneration units	5,273	5,659	5,509	5,407	5,403	5,242	4,848	4,345
Solids fired	9,009	7,872	7,117	6,263	5,709	5,172	4,618	5,292
Gas fired	1,220	1,640	2,097	1,926	1,912	1,950	1,787	2,572
Oil fired	119	120	115	58	28	26	27	33
Biomass-waste fired	168	241	295	546	964	990	1,482	1,455
Geothermal heat	0	0	0	27	79	152	344	597
Indicators for electricity production (%)								
Electricity from CHP	16.1	20.3	22.0	24.8	27.1	27.4	27.3	24.7
Electricity from non-fossil fuels	40.2	43.1	43.4	47.2	52.3	53.5	58.0	44.6
- nuclear	36.5	38.1	37.5	38.3	39.3	37.8	35.9	18.8
- domestic renewable energy sources	3.7	5.0	6.0	8.9	13.0	15.6	22.0	25.9

3.6.2 Slow Progress scenario

	2005	2010	2015	2020	2025	2030	2040	2050
Primary production (PJ)	**1,104**	**994**	**876**	**753**	**672**	**704**	**507**	**551**
Solids	985	841	665	489	369	369	108	84
Oil	24	13	13	0	0	0	0	0
Natural gas	6	8	8	8	8	8	8	8
Renewable energy sources	89	133	190	256	295	328	391	459
Hydro	8	9	9	9	9	9	9	10
Biomass and waste	81	113	162	215	236	248	265	282
Wind	0	2	5	8	13	15	17	19
Solar	0	7	8	12	20	33	61	85
Geothermal	0	2	6	12	17	23	38	63
Net imports (PJ)	**789**	**926**	**968**	**968**	**946**	**790**	**805**	**524**
Solids	-146	-118	-71	-54	-59	-89	42	-9
Oil	398	406	397	376	360	355	314	268
Natural gas and other gases	315	348	348	331	331	344	285	235
of which biogas	0	0	0	0	0	0	0	0
Nuclear	267	314	314	314	314	156	156	0
Electricity	-45	-24	-20	0	0	23	7	30
Total primary energy supply (PJ)	**1,893**	**1,914**	**1,838**	**1,714**	**1,610**	**1,486**	**1,301**	**1,063**
Solids	839	723	594	435	309	280	151	75
Oil	422	418	410	376	360	355	314	268
Natural gas and other gases	321	355	355	339	339	351	293	243
of which biogas	0	0	0	0	0	0	0	0
Nuclear	267	314	314	314	314	156	156	0
Electricity	-45	-24	-20	0	0	23	7	30
Renewable energy sources	89	127	185	250	288	320	380	447
Total primary energy supply (%)	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Solids	44.3	37.8	32.3	25.4	19.2	18.9	11.6	7.1
Oil	22.3	21.8	22.3	22.0	22.3	23.9	24.1	25.2
Natural gas and other gases	17.0	18.6	19.3	19.8	21.0	23.6	22.5	22.8
Nuclear	14.1	16.4	17.1	18.3	19.5	10.5	12.0	0.0
Renewable energy forms	4.7	6.6	10.1	14.6	17.9	21.5	29.2	42.1

	2005	2010	2015	2020	2025	2030	2040	2050
Domestic electricity generation (TWh_e)	**78.3**	**77.6**	**72.9**	**66.9**	**67.0**	**60.7**	**63.1**	**56.4**
Nuclear	27.3	29.7	29.7	29.7	29.7	15.6	15.6	0
Hydro, wind and solar	2.4	3.3	4.5	5.7	8.6	12.3	19.7	26.2
Thermal (fossil + biomass and waste)	48.6	44.6	38.7	31.5	28.6	32.8	27.8	30.2
Energy branch consumption (PJ)	**78.4**	**91.9**	**92.2**	**95.5**	**95.6**	**92.0**	**83.5**	**73.2**
Non-energy use (PJ)	**101.2**	**119.1**	**134.0**	**150.2**	**162.9**	**171.8**	**192.4**	**204.9**
Final energy demand - by sector (PJ)	**1,085**	**1,127**	**1,118**	**1,087**	**1,054**	**1,017**	**926**	**839**
Industry	436	458	454	437	419	401	350	308
Residential	241	238	234	223	215	202	176	147
Tertiary	157	151	145	137	130	124	110	98
Transport	251	279	285	290	290	291	290	286
Final energy demand - by fuel (PJ)	**1,085**	**1,127**	**1,118**	**1,087**	**1,054**	**1,017**	**926**	**839**
Solids	116	126	117	96	83	69	42	19
Oil	304	326	320	303	288	272	237	198
Natural gas and other gases	286	248	249	236	229	223	203	173
Electricity	193	199	195	192	188	187	179	178
Heat (from CHP and district heating)	144	146	142	137	131	124	108	96
Biomass/waste and solar thermal	42	82	96	124	134	143	156	175
CO_2 emissions (Mt CO_2)	**122.5**	**113.5**	**99.0**	**80.7**	**67.4**	**63.7**	**47.1**	**33.8**
Electricity and steam production	69.6	59.8	46.7	32.4	22.0	21.2	10.1	3.7
of which negative emissions from CCS	0	0	0	0	0	0	0	0
Energy branch	2.0	2.2	2.2	2.2	2.2	2.2	2.4	2.5
Industry	18.7	18.4	18.2	16.2	15.2	14.0	10.9	7.9
of which negative emissions from CCS	0	0	0	0	0	0	0	0
Residential	7.6	7.4	7.0	6.1	5.5	4.7	3.3	2.1
Tertiary	6.1	5.2	4.9	4.1	3.7	3.2	2.3	1.7
Transport	18.6	20.4	20.1	19.6	18.9	18.4	18.0	16.0
CO_2 emission index (1990 = 100)	**79.1**	**73.3**	**63.9**	**52.1**	**43.6**	**41.1**	**30.4**	**21.8**

	2005	2010	2015	2020	2025	2030	2040	2050
Main energy system indicators								
Population (million)	10.2	10.3	10.3	10.3	10.2	10.1	9.8	9.4
GDP (1000 MEUR'05)	99.9	128.1	155.8	185.6	216.9	248.8	314.1	380.6
TPES/GDP (PJ/MEUR'05)	19.3	14.9	11.8	9.2	7.4	6.0	4.1	2.8
TPES/capita (TJ/inhabitant)	188.8	186.1	178.8	166.7	157.9	147.1	132.8	112.7
Carbon intensity (t CO_2/PJ of TPES)	63.4	59.3	53.8	47.1	41.9	42.9	36.2	31.8
CO_2 emissions/capita (t CO_2/inhabitant)	12.0	11.0	9.6	7.8	6.6	6.3	4.8	3.6
CO_2 emissions to GDP (t CO_2/MEUR'05)	1225.8	886.2	635.4	434.7	311.0	255.9	149.8	88.9
Import dependency (%)	43.1	48.4	52.7	56.5	58.7	53.2	61.9	49.3
Import dependency (%, nuclear domestic)	27.1	32.0	35.6	38.1	39.2	42.7	49.9	49.3
Energy intensity indicators (1990=100)								
Industry (energy on value added)	37.6	30.6	25.6	21.0	17.7	15.3	11.2	8.5
Residential (energy on private income)	50.3	38.8	31.4	25.1	20.7	16.9	11.7	8.0
Tertiary (energy on value added)	38.4	29.6	23.0	17.8	14.2	11.5	7.8	5.6
Transport (energy on GDP)	174.4	151.2	126.9	108.4	92.9	81.1	64.0	52.1
Primary energy efficiency								
Total (MEUR/PJ)	51.7	66.9	84.7	108.3	134.7	167.5	241.4	357.9
Index (2005=100)	100.0	129.4	163.9	209.5	260.6	324.0	466.9	692.3
Carbon intensity indicators								
Electricity and heat production (t CO_2/MWh)	0.49	0.43	0.35	0.26	0.19	0.19	0.10	0.04
Final energy demand (thousand t CO_2/PJ)	46.9	45.7	44.8	42.3	41.1	39.6	37.3	32.9
Industry	42.8	40.2	40.0	37.2	36.2	34.8	31.2	25.6
Residential	31.6	31.2	29.8	27.5	25.8	23.5	19.0	14.1
Tertiary	38.7	34.4	33.5	29.8	28.2	25.5	21.0	17.3
Transport	74.0	73.0	70.54	67.5	65.1	63.4	62.0	55.8
Electricity and heat generation (MW_e)								
Total capacity	15,505	15,050	14,973	14,431	16,271	17,986	24,931	29,164
Nuclear	3,760	3,760	3,760	3,760	3,760	2,000	2,000	0
Hydro (pumping excluded)	1,198	1,256	1,264	1,270	1,262	1,246	1,246	1,246
Wind	30	410	880	1,200	1,870	2,160	2,420	2,460
Solar	1	160	530	1,040	2,900	6,050	13,200	19,500
Thermal (non-nuclear)	10,516	9,464	8,539	7,161	6,479	6,531	6,065	5,958
of which cogeneration units	5,273	5,639	5,479	5,247	5,218	5,192	4,939	4,839
Solids fired	9,009	7,157	5,517	3,729	2,288	1,661	633	105
Gas fired	1,220	1,702	1,859	1,846	2,028	2,216	1,505	1,130
Oil fired	119	120	114	57	26	5	5	3
Biomass-waste fired	168	484	989	1,298	1,715	2,026	2,606	2,162
Geothermal heat	0	0	60	231	422	622	1,316	2,558
Indicators for electricity production (%)								
Electricity from CHP	16.1	24.8	28.2	33.2	36.2	42.4	38.6	47.6
Electricity from non-fossil fuels	40.2	45.4	53.6	63.9	72.5	66.7	84.8	91.1
- nuclear	36.5	38.2	40.7	44.4	44.3	25.7	24.7	0.0
- domestic renewable energy sources	3.7	7.1	12.9	19.5	28.2	41.0	60.1	91.1

3.6.3 Innovative Approach scenario

	2005	2010	2015	2020	2025	2030	2040	2050
Primary production (PJ)	**1,104**	**994**	**875**	**753**	**671**	**705**	**504**	**547**
Solids	985	841	665	489	369	369	108	84
Oil	24	13	13	0	0	0	0	0
Natural gas	6	8	8	8	8	8	8	8
Renewable energy sources	89	133	190	256	294	329	389	455
Hydro	8	9	9	9	9	9	9	10
Biomass and waste	81	113	162	215	236	250	265	282
Wind	0	2	5	8	13	15	17	19
Solar	0	7	8	12	20	32	59	82
Geothermal	0	2	6	12	17	23	38	63
Net imports (PJ)	**789**	**891**	**924**	**909**	**862**	**662**	**679**	**367**
Solids	-146	-114	-79	-63	-76	-118	30	-26
Oil	398	385	376	355	339	314	268	197
Natural gas and other gases	315	331	327	302	285	277	218	160
of which biogas	0	0	0	0	0	14	34	33
Nuclear	267	314	314	314	314	164	156	0
Electricity	-45	-25	-15	0	0	26	7	36
Total primary energy supply (PJ)	**1,893**	**1,880**	**1,794**	**1,655**	**1,526**	**1,360**	**1,175**	**906**
Solids	839	728	585	427	293	251	138	59
Oil	422	397	389	355	339	314	268	197
Natural gas and other gases	321	339	335	309	293	284	226	167
of which biogas	0	0	0	0	0	14	34	33
Nuclear	267	314	314	314	314	164	156	0
Electricity	-45	-25	-15	0	0	26	7	36
Renewable energy sources[32]	89	127	185	250	288	322	380	447
Total primary energy supply (%)	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Solids	44.3	38.7	32.6	25.8	19.2	18.4	11.7	6.5
Oil	22.3	21.1	21.7	21.5	22.2	23.1	22.8	21.8
Natural gas and other gases	17.0	18.0	18.7	18.7	19.2	20.9	19.2	18.5
Nuclear	14.1	16.7	17.5	19.0	20.6	12.0	13.3	0.0
Renewable energy forms[32]	4.7	6.7	10.3	15.1	18.8	23.6	32.4	49.4

[32] Does not include imported biogas. Imported biogas is included in “Natural gas and other gases”.

	2005	2010	2015	2020	2025	2030	2040	2050
Domestic electricity generation (TWh_e)	**78.3**	**76.7**	**70.6**	**65.3**	**64.7**	**57.96**	**61.0**	**52.5**
Nuclear	27.3	29.7	29.7	29.7	29.7	16.4	15.6	0
Hydro, wind and solar	2.4	3.3	4.5	5.7	8.6	12.3	19.7	26.2
Thermal (fossil + biomass and waste)	48.6	43.7	36.5	30.0	26.4	29.2	25.6	26.3
Energy branch consumption (PJ)	**78.4**	**91.9**	**92.2**	**91.3**	**84.7**	**82.2**	**75.2**	**63.7**
Non-energy use (PJ)	**101.2**	**119.1**	**134.0**	**150.2**	**162.9**	**171.8**	**192.4**	**204.9**
Final energy demand - by sector (PJ)	**1,085**	**1,109**	**1,074**	**1,018**	**962**	**904**	**780**	**669**
Industry	436	453	442	418	395	372	314	267
Residential	241	233	220	201	185	165	130	97
Tertiary	157	148	137	124	114	104	85	69
Transport	251	275	275	274	269	263	251	236
Final energy demand - by fuel (PJ)	**1,085**	**1,109**	**1,074**	**1,018**	**962**	**904**	**780**	**669**
Solids	116	133	120	101	86	71	44	18
Oil	304	320	308	282	256	231	176	114
Natural gas and other gases	286	233	221	200	182	170	140	109
Electricity	193	198	190	186	182	179	171	170
Heat (from CHP and district heating)	144	143	135	126	117	107	87	72
Biomass/waste and solar thermal	42	83	101	123	140	147	161	185
CO_2 emissions (Mt CO_2)	**122.5**	**112.6**	**95.6**	**76.9**	**61.7**	**52.5**	**31.4**	**14.6**
Electricity and steam production	69.6	59.5	45.5	31.8	21.1	16.4	5.3	-1.1
of which negative emissions from CCS	0.0	0.0	0.0	0.0	0.0	-2.9	-2.9	-2.9
Energy branch	2.0	2.2	2.2	2.2	2.2	2.2	2.4	2.5
Industry	18.7	18.5	17.6	15.9	14.3	12.5	7.2	2.7
of which negative emissions from CCS	0.0	0.0	0.0	0.0	0.0	0.0	-1.5	-3.0
Residential	7.6	7.3	6.4	5.2	4.3	3.4	1.8	0.7
Tertiary	6.1	5.1	4.5	3.7	3.1	2.5	1.4	0.6
Transport	18.6	20.0	19.3	18.1	16.7	15.5	13.2	9.2
CO_2 emission index (1990 = 100)	**79.1**	**72.7**	**61.7**	**49.7**	**39.9**	**33.9**	**20.3**	**9.4**

	2005	2010	2015	2020	2025	2030	2040	2050
Main energy system indicators								
Population (million)	10.2	10.3	10.3	10.3	10.2	10.1	9.8	9.4
GDP (1000 MEUR'05)	99.9	128.1	155.8	185.6	216.9	248.8	314.1	380.6
TPES/GDP (PJ/MEUR'05)	19.3	14.7	11.5	8.9	7.0	5.5	3.7	2.4
TPES/capita (TJ/inhabitant)	188.8	182.8	174.4	161.0	149.7	134.7	120.0	96.0
Carbon intensity (t CO_2/PJ of TPES)	63.4	59.9	53.3	46.5	40.4	38.6	26.7	16.1
CO_2 emissions/capita (t CO_2/inhabitant)	12.0	10.9	9.3	7.5	6.1	5.2	3.2	1.5
CO_2 emissions to GDP (t CO_2/MEUR'05)	1225.8	879.1	613.6	414.6	284.6	210.9	99.9	38.3
Import dependency (%)	43.1	47.4	51.5	54.9	56.5	48.7	57.8	40.5
Import dependency (%, nuclear domestic)	27.1	30.7	34.0	35.9	35.9	36.6	44.5	40.5
Energy intensity indicators (1990=100)								
Industry (energy on value added)	37.6	30.2	24.9	20.1	16.7	14.2	10.1	7.3
Residential (energy on private income)	50.3	38.0	29.5	22.6	17.8	13.9	8.6	5.3
Tertiary (energy on value added)	38.4	29.0	21.8	16.2	12.4	9.7	6.0	3.9
Transport (energy on GDP)	174.4	148.9	122.4	102.5	85.9	73.4	55.3	43.0
Primary energy efficiency								
Total (MEUR/PJ)	51.7	68.1	86.8	112.1	142.1	182.9	267.2	419.9
Index (2005=100)	100.0	130.9	166.8	215.4	272.9	351.4	513.3	806.5
Carbon intensity indicators								
Electricity and heat production (t CO_2/MWh)	0.49	0.43	0.35	0.27	0.19	0.18	0.09	0.02
Final energy demand (thousand t CO_2/PJ)	46.9	45.83	44.58	42.1	39.9	37.5	30.3	19.7
Industry	42.8	40.8	39.9	38.0	36.1	33.6	23.0	10.0
Residential	31.6	31.4	29.2	25.8	23.5	20.5	13.9	7.2
Tertiary	38.7	34.3	33.0	30.1	27.6	23.7	16.7	9.0
Transport	74.0	72.6	70.2	65.9	62.0	59.0	52.6	39.0
Electricity and heat generation (MW_e)								
Total capacity	15,505	14,850	14,508	13,866	15,505	17,516	24,530	28,367
Nuclear	3,760	3,760	3,760	3,760	3,760	2,000	2,000	0
Hydro (pumping excluded)	1,198	1,256	1,264	1,270	1,262	1,246	1,246	1,246
Wind	30	410	880	1,200	1,870	2,160	2,420	2,460
Solar	1	160	530	1,040	2,900	6,050	13,200	19,500
Thermal (non-nuclear)	10,516	9,264	8,074	6,596	5,712	6,060	5,664	5,161
of which cogeneration units	5,273	5,439	5,179	4,957	4,816	4,687	4,503	4,008
Solids fired	9,009	7,199	5,348	3,587	2,145	1,528	581	106
Gas fired	1,220	1,472	1,765	1,741	1,872	2,000	1,377	714
Oil fired	119	119	113	56	24	18	8	3
Biomass-waste fired	168	473	788	982	1,255	1,907	2,449	2,047
Geothermal heat	0	0	60	230	417	607	1,249	2,292
Indicators for electricity production (%)								
Electricity from CHP	16.1	23.9	27.0	32.6	35.8	39.4	36.2	43.3
Electricity from non-fossil fuels	40.2	45.8	54.0	63.0	71.5	68.2	84.9	93.6
- nuclear	36.5	38.7	42.0	45.4	45.9	28.3	25.6	0.0
- domestic renewable energy sources	3.7	7.1	12.0	17.6	25.6	39.9	59.3	93.6

4 General recommendations for priorities of energy policy

A targeted energy policy strategy is necessary in order to realize the results of the Innovative Approach scenario. Such a policy strategy has to combine a consistent and comprehensive set of policies and measures of all types and in all sectors.

Even under BAU conditions, general technical progress leads to more efficient and environmentally sound products and processes. However, it is not sufficient to simply counterbalance growing energy consumption. In order to limit global warming to a maximum 2 ^{o}C average temperature increase above pre-industrial level, more active strategies are required. Moreover, comprehensive long-term climate-friendly actions will bring a range of further benefits, including less dependency on foreign sources of energy, cost savings across all sectors, reduction of local pollution due to a switch-over to cleaner sources and productions and increased job opportunities in the fields of energy efficiency and renewables (Wuppertal Institute 2005).

This chapter includes a small overview on policy instruments and measures in energy efficiency and in renewable energy fields, furthermore it summarises the regulatory aspects of a sustainable energy sector development.

4.1 Energy efficiency support schemes

Greater energy efficiency saves consumers and businesses money while reduced energy use decreases the adverse environmental impacts of energy production and conversion. In particular, energy efficiency is viewed as a strategy to reduce carbon dioxide emissions and to meet the Kyoto Protocol targets. Furthermore energy efficiency improvements can provide social benefits such as increased productivity and employment, reductions in the high energy cost burden faced by low-income households, improved comfort and public health, enhanced national security, and conservation of finite resources such as oil, coal and natural gas.

Energy efficiency improvements result from ongoing technological progress, response to rising energy prices, and competitive forces pressuring businesses to cut all types of costs including energy costs. In addition, governments have implemented a wide range of policies and programs. These policies and programs are introduced in this section.

In general six different general types of measures can be distinguished:

- Information and Advice
- Financial Incentives
- Market-based approaches and Services
- Legal regulation and standards
- Stakeholder networks and voluntary agreements
- Institutional measures

These different types of measures can be applied to address the following energy users:

- Industry and service sector

- Private households
- Public sector
- Transport sector
- Energy service companies (cross-cutting)

The following subsections provide a detailed description of various measures in the different sectors which can be used to increase the energy efficiency of the Czech Republic (Schüle et al 2007, IEA 2005b). The measures are classified in the scenarios in different ways: Service and public sector belong to one group in the model, while industry is another one. Nevertheless, from the policy measures point of view it is beneficial to emphasise the exemplary role of the public sector and to introduce these measures in a different section, while industry and services sector incentives can be introduced in one group, because they are usually similar actions. Energy Service Companies play an essential role in the energy efficiency improvement; therefore a separate section tackles these incentives.

4.1.1 Industry and service sector

Information and advice

The provision of information and advice (e.g. information campaigns, energy audits) is one of the standard energy efficiency improvement measures within the industry and service sector, usually complemented by financial incentives. Mandatory or voluntary energy audits could be required for large energy consumers or for companies and private investors applying for subsidies or low interest loans. Information campaigns can play a relevant role in the tertiary sector, such as energy saving guidelines to disseminate technical know-how, stimulus programs, training of specialists, and Internet-based information tools for improving energy management and energy efficiency in office equipment (Schüle et al 2007).

Financial incentives and marked-based approaches

Loan schemes, grants or direct subsidies for promotion of energy efficiency and renewable energies are offered in many EU member states. These direct financing measures are usually complemented by rebates in taxation for investments in energy efficiency. The financial incentives are especially used for energy efficient technologies in lighting, compressed air, heating, ventilation and air conditioning. Beside the financial support for energy efficient appliances there are mainly additional incentives targeting the promotion of renewable energies or combined heat and power (CHP).

Legal regulation and standards

The main target of obligatory measures and legal regulations is to improve the energy performance of old and new buildings in the industry and service sector. Furthermore mandatory standards aim to encourage the use of energy saving products, i.e. appliances, through the setting of a minimum requirement of energy efficiency for new products. Another instrument could be the introduction of mandatory metering systems for large energy users.

The use of Energy Saving Certificates, Energy Efficiency Credits or white certificates could be another energy efficiency stimulating instrument. These documents are certifying that a certain reduction of energy consumption has been achieved. Under such a system, participants are required to undertake energy efficiency measures and achieve energy savings in their annual energy use. The certificates are given to the producers, suppliers or distributors of electricity, gas and oil whenever an amount of energy is saved whereupon the participants can use the certificate for their own target compliance or it can be sold to (other) parties who cannot meet their targets. If the holder of certificates fails to achieve a pre-defined percentage drop of his annual energy consumption, he is required to pay a penalty. The white certificates are usually combined with an obligation to achieve a certain target of energy savings.

Voluntary agreements and stakeholder networks

The long-term voluntary agreements represent a different strategy: The government concludes long-term agreements for improving energy efficiency with the national industry in a large number of sectors. The realization of these long-term agreements occurs in consultation with the relevant public institution which sets the energy efficiency goals for each company, linked to concrete measures and an implementation plan.

Closely related to the concept of voluntary agreements are voluntary networking approaches between governmental authorities and business representatives. The voluntary networking approaches establish networking and information programs for large industrial energy users and education programs for specific target groups, in which information on energy efficient measures in industries and companies is provided.

Institutional measures

The institutional measures aim to establish a differentiated structure of advisory centres and institutional funding structures for further activities in order to support relevant stakeholders and parties (energy companies, housing associations, private households, tertiary sector and construction sector) in their activities to improve energy efficiency. On the regional level, „energy centres" provide basic information and advice on energy efficient measures for small and medium enterprises (SMEs).

Experts and representatives of the district and municipal administration work together in the local advisory schemes in order to help local businesses and companies in the industry and tertiary sector to adopt district and municipal programs. The majority of loans is offered to small and medium sized enterprises for qualifying energy efficiency investments. An energy efficiency fund can furthermore provide a range of free services including telephone and face-to-face advice, energy audits and reports, and references to appropriate sources of funding or further specialist support (Schüle et al 2007).

4.1.2 Private households sector

Energy efficiency measures addressing private households can be separated into two main groups: one targeting the improvement of the energy performance of buildings, the other intending to reduce electricity use (Schüle et al 2007).

Information and advice

As in the industry and tertiary sector, the provision of information and advice for the improvement of the energy performance of buildings plays the most important role in the private household sector too. There are general information and networking campaigns to promote a broader use of renewable energy and energy-efficient technologies, higher insulation standards in the building sector, as well as to promote the use of energy-efficient appliances, including the reduction of stand-by use. This can be realized through various forms like a general advertising campaign, a website, provision of Carbon footprint calculators, improved energy bills or mandatory smart metering schemes.

Beside of the general campaign, further initiatives can be addressed specifically to decision makers and groups of actors with relevant influence on investment decisions, e.g. master builders, plumbers, property developers and managers, manufacturers of (prefabricated) houses, and procurement operators.

Education plays an essential role in the long-term diffusion of energy efficiency technologies in the private household sector. In order to build awareness on energy efficiency, its cost and its environmental impacts, several aspects are important:

- Informing consumers about the fact that inefficient energy use causes extra costs and environmental pollution.
- Encouraging individual responsibility and small changes in every day-behaviour.
- Empowering individuals to recognise their role in the challenge and to use their power to collectively make the difference.

Financial incentives

Just like in the industry and service sector, tax reductions, loan schemes, grants or direct subsidies can be offered to improve the energy performance of buildings in the private household sector. The programs can focus on both the improvement of the energy efficiency of buildings and the use of renewable energies or CHP-systems.

Legal regulation and standards

Legal regulations may on the one hand target the energy efficiency standards of new buildings. These can include the promotion of the use of decentralised renewable energies, the obligation for new low-energy buildings, the connection to district-heating and natural gas systems or the prohibition of the electric heating use.

On the other hand legal regulations can require further specific information on the energy performance of existing buildings, major renovations in old buildings (e. g. relating to the replacement of roofs, windows, as well as oil and gas boilers and the change of heat supply), energy improvements, or the implementation of an energy label. A mandatory inspection scheme for heating systems targets the quality assurance of energy efficient heating. The legal regulations can include the improvement of energy efficiency in social housing, or the upgrade of energy performance of homes occupied by low-income families (Schüle et al 2007).

4.1.3 Public sector

In order to introduce sustainable energy management and procurement in the public sector the main objectives of the measures in the public sector are:

- strengthening the energy performance of public buildings
- improving the building envelope
- improving energy efficiency requirements for new buildings or for the refurbishment of existing buildings

Information and advice

Information and advice for the public sector is provided by information campaigns, audits and labelling schemes. Additionally, the government could provide financial support for energy efficiency modernization projects of public buildings.

Furthermore so-called 'Green Leaders' can be assigned in each public institution. Their major activity would be to commission an energy audit in the public buildings.

Financial incentives, market-based approaches and services

Investment programs and subsidies for the public sector could be further important financial instruments in order to promote energy efficiency, similar to the industry, the tertiary or private household sectors. The incentives can cover a retrofit program for existing public buildings or subsidies available for high energy performance new buildings.

Legal regulation and voluntary agreements

The requested improvement of the energy performance of public buildings can be addressed by regulatory measures, e.g. aim at reaching carbon neutral or climate neutral central government buildings by certain time.

Voluntary agreements and mandatory information measures for municipal and public sector buildings can furthermore improve the energy efficiency performance of the public sector. The design ranges from mandatory green public procurement programs to less binding regulations, where energy efficiency criteria have to be taken into consideration in public investments. These can include energy saving targets for the public sector or the requirement to produce annual reports on energy efficiency actions and the documentation of the progress regarding this target (Schüle et al 2007).

4.1.4 Transport sector

The spectrum of measures in the transport sector consists of measures e.g. addressing the optimization of energy-use in vehicles (1), the optimization of the mobility management on existing transport infrastructure (2) and measures aiming at changing the modal split of used means of transport (3) (Schüle et al 2007).

Optimization of energy-use in vehicles

There are several types of measures regarding the optimization of energy-use in vehicles and the technical increase of energy efficiency in the transport sector:

- promoting energy efficient vehicles through grants and subsidy schemes
- focused public awareness campaign, public procurement strategies
- labelling scheme or emission limits for new cars
- introduction of annual car emission tests
- optimal use of existing technology, *ecodriving trainings* and courses have been promoted
- providing information on optimal tyre pressure and liquids used in passenger cars and traffic.

Another group of measures is related to the improvement of the national transportation infrastructure, e.g. investments in rail infrastructure. At a more strategic level research on energy-efficient, environmentally friendly transportation and innovative vehicle concepts can be supported.

Furthermore, the introduction of environmental taxation has its various effects on the use of vehicles, either via taxation of fuel oils or via introduction of emissions-related road taxes can optimize the vehicle energy-use.

Optimization of mobility management

As regards optimizing the mobility management of existing transport infrastructure, several types of measures can be implemented:

- Mandatory speed restrictions
- Promoting information technology in transport through the use of telematics in order to increase capacity utilisation and to reduce traffic
- Promoting car-sharing and car-pooling
- Promoting mobility managements in public and private institutions or travel centres
- Improving goods and passenger rail transport

Change of modal split

Change of modal split can be supported by several measures:

- information campaigns
- expansion of public transport, use of energy efficient public transport vehicles
- establishment of a school bus system
- encouraging the use of bicycle transport and pedestrians
- promoting teleworking

- promoting changes in spatial and regional planning and residential housing development towards environmentally friendly use of means of transportation

4.1.5 Energy Service Companies

The activities and measures addressing energy distributors, distribution system operators, retail energy sales companies or other energy service companies (ESCOs) range from the creation and stimulation of framework conditions for energy services through the provision of energy services up to the mandatory commitments imposed upon ESCOs. Energy Service Companies are business companies promoting energy efficiency improvements (and also renewable energy projects) in many case on a turn-key basis. The main characteristics of the energy service companies are

- ESCOs guarantee energy savings and/or provision of the same level of energy service at lower cost.
- The remuneration of ESCOs is directly tied to the energy savings achieved.
- ESCOs can finance or assist in financing the operation of an energy system by providing a savings guarantee.

Energy services include a wide range of activities, such as energy analysis and audits, energy management, project design and implementation, maintenance and operation, monitoring and evaluation of savings, property management, and equipment supply (ManagEnergy 2009).

Information, advice, financial incentives and market-based approaches

The information incentives for Energy Service Companies should make information more accessible concerning the saving of both fuels and energy and furthermore enforce the energy saving responsibility of energy companies.

Stimulating a market for ESCOs provides more energy services. This will raise awareness at the supply and demand side of the energy service market and develop confidence in the activities of supplying companies.

Energy end-use efficiency conducted by distributors can be provided by financing instruments and promoted by information awareness campaigns.

Networking approaches and voluntary agreements

Energy conversion agreements for the energy sector cover three agreement sectors: the power plant sector, the district heating sector and the electricity transfer and distribution sector. The actions under this agreement include measures addressing the production of district heating, the establishment of a district heating network, the internal usage of energy by the companies, and the enhanced efficiency of the customer’s energy usage.

Legal regulation and standards

Legal regulations and standards in the energy service sector mainly introduce the White Certificates scheme. The White Certificates scheme combines voluntary agreements and legal regulations. This obligation may be honoured either by conducting operations directly, by resorting to related service companies, or by purchasing the corresponding White Certificates on the market (Schüle et al 2007).

4.2 Renewable energy support schemes

This section summarises a wide range of policies and measures, which are used to promote energy production from renewable energy sources. In general, measures taken to promote renewables can be grouped into eight categories:

- Information and education campaigns to increase awareness of renewable energy technology performance, availability and incentives
- Voluntary actions, usually between governments and industries/utilities
- Regulations and standards on energy use, environmental performance
- Energy or carbon taxes
- R&D subsidies on renewable energy technologies
- Economic and fiscal incentives: subsidies, grants, tax allowances
- Other price-based incentives such as feed-in tariffs and fixed premiums
- Quantity based incentives such as tendering system, quota obligations and tradable green certificate schemes

While the information and education campaigns, the regulations and standards, the voluntary actions and green pricing are indirect support schemes, the economic and fiscal incentives, R&D subsidies and feed-in tariffs for renewable energy sources belong to direct support instruments. The indirect incentives aim at increasing the demand for renewable energy and they do not target the renewable energy investors directly. On the other hand the direct schemes provide support directly to renewable energy projects.

Table 4: Classification of the different renewable electricity support schemes

	Direct incentives		**Indirect incentives**
	Price-driven	**Quantity-driven**	
Investment focused incentives	Investment incentives	Tendering system	Environmental taxes
	Tax incentives		
Generation based incentives	Feed-in tariffs	Quota obligation and tradable green certificates scheme	

Original source: Ragwitz et al 2006.

4.2.1 General support schemes

The general support schemes support the overall use of renewable energy sources in all application fields. The information and education programs and voluntary actions try to increase the knowledge and information about these alternative energy resources, while the energy or carbon taxes reduce the market price difference between the conventional and renewable energy sources. The use of these overall support schemes is essential to gain a broad general acceptance and raise public awareness.

Information and education programs

Many countries have initiated information and education measures which aim to get over the lack of information on renewable energy sources. The spectrum of different information and education programs is quite broad and ranges from television advertisements to increase general environmental awareness to more specific education in schools and universities to support targeted information to certain groups. The effect of these programs is rather long term, therefore it is difficult to measure.

Voluntary actions

Voluntary actions between governments and either utilities or industries are usually used at the beginning of the renewable energy development. Both voluntary actions and green pricing are attractive from a public funding perspective as they may require little or no public funds beyond setting up and managing the scheme. The voluntary actions can range from formalized and binding negotiated targets to more informal approaches. This type of policy instrument is mainly used in countries with long voluntary action traditions.

Energy or carbon tax

There are different taxes levied on the amount of environmentally hazardous material or carbon dioxide released in the energy sector which help to internalize the negative external effects of conventional energy supply and to validate the polluter pays principle. These taxes could promote the use of renewable energy sources and reduce the competitiveness of conventional energy fuels by making the use of conventional energy fuels more expensive. The impacts of the tax depend on the features of the regulation and the future increase of the amount of the tax. At the introduction of the tax it is important to ensure long term planning reliability.

The energy and carbon taxes are efficient revenues and incentives which cause state incomes instead of expenditures. Nevertheless, the disadvantage of the energy or carbon taxes is the relatively high cost of collection and redistribution.

The energy and carbon taxes are described more detailed in section 4.3.2.

4.2.2 Renewable electricity support instruments

The European member states use different renewable electricity support measures to reach the overall renewable energy targets of the European Union. Independently from the main support system, numerous researchers identified other approaches whose combination is considered to be the explanation of their success (Ragwitz et al 2006):

- Importance of a clear, consistent and coherent policy avoiding stop-and-go measures
- Early R&D phase encouraging technological variety
- Supporting broad range of renewable technologies
- Ensuring investment security
- Encouraged market creation and development
- The industrial policy component fostered a domestic equipment industry
- Policy built on and encouraging the social legitimacy of renewable energies
- Ensuring information and knowledge transfer

The Energy Technology Perspectives study (IEA 2008b) emphasizes that the combination of both more and less mature renewable energy technologies will play a major role in achieving deep CO_2 emission cuts in a competitive fashion.

The presence of non-economic barriers has a significant negative impact on the effectiveness of policies to develop the usage of renewable energy sources, such as administrative hurdles (e.g. planning delays and restrictions, lack of co-ordination between different authorities, long lead times in obtaining permissions), grid access, electricity market design, lack of information and training, and social acceptance. A minimum level of remuneration appears necessary to encourage the deployment of renewable energy sources (strongly depending on the used fuel and size of the installation), and the guaranteed high investment stability is required for the long-term success too. In the case of bioenergy production it is necessary to ensure the sustainability, therefore the use of a life-cycle assessment is required (Prantner 2007).

Investment subsidies

At the beginning of renewable energy development, investment subsidies were often used all over the world as an incentive to investors, normally given on the basis of the rated power (in kW) of the generator. The investment subsidies – similar to the energy or carbon tax – could promote the competitiveness of renewable energy sources, because subsidies make the renewable energy investments less expensive. The subsidies establish an incentive for the development of renewable energy projects as a percentage over total costs, or as a predefined amount of money per installed kW. The level of the incentives is usually technology-specific. Investment subsidies provide a certain security and financial stability for investors in order to reach the cost differences between conventional and renewable technologies.

However, the state has more direct control on renewable projects through direct investment subsidies. It is generally acknowledged that systems relating the amount of support to the size of the RES rather than the production of electricity are not ideal because they lead to less efficient installations. Therefore, if the government chose this type of supporting market mechanisms, the incentive should be related to efficiency of electricity production as well. Furthermore the clear, consistent and coherent long term policy is important in order to ensure investment security. The subsidies should include a wide range of technology differences.

The costs of the support scheme will be paid either by the taxpayer or by an environmental fund. Investment subsidies can be more effective if they are combined with other incentives (Prantner 2007).

Renewable energy funds

The main advantages of renewable energy funds are their flexibility to receive and channel funds from different sources and to use the resources according to public interest. The funds can be used to support R&D and demonstration projects, public campaigns and NGO participation. On the other hand, the main disadvantage is their related lack of transparency, which can lead to high transactions and monitoring costs (Prantner 2007).

Feed-in tariffs and fixed premium systems

Mechanisms based on fixed feed-in tariffs (FITs) have been widely adopted throughout Europe. Feed-in tariffs are generation-based price-driven incentives. The scheme consists of two parts: On the one hand it ensures a purchase obligation on utilities (supply companies or grid system operators) and on the other hand it sets the price to be paid for renewable electricity per kWh generated in renewable power plants. The government regulates the tariff rate.

The support scheme has several modalities and design choices:

- Fixed feed-in tariff system versus fixed premium systems: Fixed FITs provides total payments per kWh, while the latter fixes only a premium to be added to the electricity price
- Base calculation to fix the level of support: FITs can be calculated according to the „avoided costs" of conventional power or the FITs can be linked to the average price of electricity in order to ensure the competition between conventional and renewable technologies
- Technologies supported and technology-specific support: differentiation between different technologies is common. Less mature technologies receive higher levels of support. The level of support is usually declining over time.
- Different level of support according to the sites, considering the availability of the resource and the different generation costs
- Time period of FIT: The time of renewable electricity generation can be considered to differentiate support (within a day, year or season)
- Frequency setting the FIT: tariffs can be fixed annually or for a longer period

- Minimum period for guaranteed payments: payment periods can be guaranteed for a shorter or longer period
- Actors paying for the FIT: the costs of the system can be financed by final consumers or by tax payers
- FIT can be paid to new capacity applications only or to existing capacity as well

The purchase obligation provides clear and transparent requirements for supported technologies, electricity prices and quantities and it sets up legal circumstances for the electricity market actors.

The main determinant of a successful FIT model is the level of the tariff. Apart from the level of the tariff, its guaranteed duration represents an further important parameter for assessing the actual financial incentive. Moreover the payment mechanism has to be supplemented by adequate grid connection conditions and a well functioning planning framework. Good planning and grid connection frameworks are a precondition for any mechanism to be successful.

The main advantage of a FIT is its flexible structure, which allows to distinguish between different technologies and it often encourages a better planning for the investors, therefore it decreases the investors' risk. In principle, the level of the tariff can be changed at any time or removed by repealing the law.

In short time period FITs are not the most efficient support scheme, however, they provide long-term stability for the investors, which is necessary for the realization of renewable electricity innovations.

Widely used alternatives to feed-in tariffs are fixed premium systems. The mechanism based on a fixed premium/environmental bonus reflects the external costs of conventional power generation that could establish fair trade, fair competition and level the playing field in the internal electricity market between renewable energy sources and conventional power sources. Together with taxing conventional power sources in accordance to their environmental impact, fixed premium systems are, theoretically, the most effective way of internalizing external costs.

From a market development perspective, the advantage of a price premium is that it allows renewables to penetrate the market very quickly, if their costs drop below the electricity price plus premium. If the premium is set at the "right" level (theoretically at a level equal to the external costs of conventional power), it allows renewables to compete with conventional sources, without the need for politicians to set quotas. The fixed premium systems are more uncertain from the perspective of a renewable plant owner, the total price received per kWh (electricity price plus the premium) is less predictable than under a FIT because it depends on a changing electricity price. In practice, to count the suitable fixed premiums for renewable energy technologies is very complex.

Tenders

Tendering systems are quantity driven mechanisms. The tender means that developers of renewable energy projects are invited to bid for a limited renewable energy capacity in a given (long-term) period. The companies that bid to supply electricity at the lowest cost win the contracts. The difference in price between these contracts and the price of conventional power represents the additional costs of producing green electricity.

Theoretically, tendering systems lead to an optimal market development, however the lack of continuity of government policy and the failure of long-term commitments (so called stop-and-go features) can hinder the stable market development (Prantner 2007).

Tradable Green Certificates

The primary characteristics of a quota-based system are gaining a particular quantity of national output from renewable energy sources determined by policy makers and introducing market mechanisms to attain that quota.

The Tradable Green Certificate (TGC) system is a market-oriented generation-based quantity-driven instrument. The support system consists of two parts:

- Quota obligation: market participants have to have a certain share of electricity from renewable sources in their energy production or consumption
- Green certificates: the renewable electricity producers receive Green certificates for the produced electricity, which can be traded on a separate market

Electricity from renewable sources will be purchased ordinarily on the power market and receives revenue for the sale. Furthermore the renewable electricity producer receives Green Certificates from the State which can be sold and provide extra revenue. This means, that the renewable electricity producers receive revenues both from the sale of the electricity and the sale of the certificates. If a TGC market works effectively, the price of a certificate will reflect the difference between the market price of electricity and the generation costs of new renewable generating capacity. The value of a certificate represents the additional cost of producing renewable electricity compared to conventional sources.

The renewable quota obligation is increasing over time in order to stimulate investments in the renewable power generation. The failure to comply with the quota obligation must lead to a sufficient penalty. If there is lack of legal and financial consequences or the level of the penalty is not stipulating, the participating companies will not fulfil their obligation.

The system is designed to promote investments in the least-cost renewable electricity sources, and to introduce a competition between different renewable energy technologies without any differentiation.

With daily setting of prices, the TGC model is more risky for the renewable energy investors, therefore this support scheme is less suitable for less mature technologies. In order to ensure the development of a wide range of technologies, it is important to apply other types of support schemes as well.

4.2.3 Renewable heat production support schemes

There is a broad range of policy instruments to support the heat production from renewable energy sources (Bürger et al 2008). The measures can be grouped into four categories:

1. Fiscal instruments

2. Purchase, sale and remuneration obligations
3. Use obligations
4. Other regulatory approaches

The following subsectors summarize the policy recommendations to encourage heat production from renewable energy sources.

Fiscal instruments

In many cases, heat utilization from renewable energy sources is still more expensive than fossil fuel use. The introduction of various fiscal instruments could either make fossil fuels more expensive for the consumer or reduce the price of renewable energies through the adoption of appropriate measures. The following options are available in principle:

- Creating new and/or increasing existing taxes on fossil fuels
- Subsidizing renewable energy from current tax revenue (government grants)
- Providing different types of tax breaks for renewable energy systems (e.g. tax subsidies, exemption of VAT)
- Introducing new revenues to promote renewable energy, allocation of public investment grants

Purchase, sale and remuneration obligations

This section includes all the instruments similar to the price or quota regulation of support instruments for electricity production from renewable energy sources (see chapter 4.2.2).

The Quota Model for renewable heat includes obligations for traders to purchase or sell specific amounts from heat products produced from renewable energy, such as the quota obligation support scheme for electricity from renewable energy sources.

The Bonus Model is a rather new concept, similar to the classic feed-in scheme for renewable electricity which can be characterized as a purchase/remuneration obligation with fixed reimbursement rates. The renewable heat system operators receive a fixed price per kWh corresponding to the amount of heat they produce. Like the feed-in tariff system, the Bonus Model can easily be adjusted to the specific needs of the different renewable heat technologies.

However, the are some differences between the heat and the electricity sector structure. The relationship between renewable plant operators and energy users is different. While electricity is fed into the grid which allows to distribute it, heat is mainly produced in individual heat systems and the homogeneous country-wide transmission and distribution grid is missing. Therefore Bürger et al (2008) propose the introduction of a pooling organization to aggregate the actions and bonus payments for the operators. All producers are obliged to join a pooling organization in order to receive the renewable heat bonus. Furthermore, for small renewable heat system operators these bonus payments could be aggregated over years and paid as an investment fund. Larger installations would receive a bonus payment depending on the amount of renewable heat produced.

The fossil fuel traders are the ones paying for costs that result from the Bonus Model. It can be assumed that they will pass the additional costs on to their consumers so basically any ordinary fuel consumer has to finance the support scheme.

Use obligations

The use obligation means an obligation imposed on specific parties to utilize renewable heat to a defined extent in new installations or replacement of heating systems. The advantage of this instrument is the easy method of operation and communication. On the other hand, its disadvantages result from its technology-specific effects and the long-term structural change in the heat sector, which favours more network-based supply systems.

Other regulatory approaches

Other regulatory approaches can include proposals on how a new instrument to promote renewable energy in the heat market can be integrated into the existing European emission trading system. The easiest way is to expand the scope of application of this regulation and include smaller installations under 20 MW firing capacity as well. However, this option would induce enormous transactions costs. Further possible options are either the integration of fossil fuel suppliers into emissions trading by imposing a ceiling on CO_2 emissions caused by the burning of fossil fuels initially placed on the market by them, or integrating measures aimed at promoting renewable energy utilization in the heat market as a contribution to CO_2 emissions reduction (integration of CDM measures) into the emission trading scheme. However, it is difficult to quantify the renewable heat production increase through these regulatory approaches (Bürger et al 2008).

4.2.4 Support measures for biofuels

Biofuels are mainly used in the transport sector. The biofuel sector and the biofuel support schemes are tightly connected to other sectors, especially to the agricultural sector, therefore the overview of various policy measures follows the stages in the production-use chain of biofuel:

- Production of biomass
- Conversion of agricultural biomass to biofuels
- Distribution of biofuels
- Biofuel consumption (OECD 2008)

Measures affecting the production of biomass

In order to reduce the production cost of agricultural crops or biomass as a feedstock for biofuels, one method is to provide a direct subsidy per output of biomass produced to a farmer, a producer of wood etc.

Regardless of the end-use of agricultural products (i.e. for energy, food, feed or fibre use), their production has been supported by general input subsidies in some OECD countries. While not a direct subsidy for biomass production, such subsidies have, however, an indirect effect on the production cost of agricultural biomass by reducing the price paid by farmers for variable inputs. Among these inputs are fertilizers, feed, seeds, energy, water, electricity, transportation, and insurance subsidies.

Measures affecting the conversion of agricultural biomass

Support for biofuels production is often oriented on the reduction of infrastructure costs. For subsidizing, conversion costs, capital grants, guaranteed loan systems, capital allowances or licences are widely used. Capital grants allow the government to support part of the investment cost faced by a producer for a renewable fuel installation.

A further way to support renewable fuel production is a reduction of production costs through the granting of an amount of money proportional to the quantity of biofuel or energy output. This support can take the form of a direct subsidy per unit of output of biofuel produced or the form of an income tax credit.

Support of biomass can furthermore include a guarantee for a minimum price that a renewable fuel producer has to receive. This guaranteed minimum price of purchase for the biofuel produced is similar to the feed-in tariff or green bonus measures used for renewable electricity support.

Support for agricultural feedstock or biomass conversion can take the form of a quantitative requirement like a quota obligation scheme of the renewable electricity support, however this type of measure has not been widely employed.

All of these orientations (reductions of infrastructure and production costs, guaranteed prices and quantitative requirements) are generally combined in one form or another to support biofuel production.

Measures affecting the distribution of biofuels

Measures affecting the distribution of biofuels can reduce the distribution costs or define qualitative requirements.

In order to reduce the cost of distribution, fuel tax credits, income tax credits or direct subsidies are offered to biofuel blenders. Under the fuel tax credit arrangement, it is allowed to claim a tax credit for the biofuel component in the fuel mixture. In case of an income tax credit, the amount of the credit will be imputed on the income instead of the fiscal liability. A direct subsidy can also be granted to reduce the distribution costs of biofuels.

Quantitative requirements can be used on both distributed quantities and distributing infrastructures. On the distribution side, a quota obligation scheme is one procedure which can be implemented to ensure supply. In relation to distributing infrastructure quotas, governments can require, for example, that petrol stations sell a certain amount of renewable fuels. Penalties can be applied to ensure compliance with the quota objectives.

Support measures for renewable fuel consumption

In order to support the consumption of renewable fuels, one approach is to offer a price reduction for the biofuel.

An income tax credit on the purchase of renewable infrastructure such as flex-fuel engine technology in cars that run on pure biofuel or blends with fossil based fuels etc., can also be granted. Within this measure, a percentage of the total cost of the renewable fuel infrastructure can be deducted from the income tax of a household or a firm.

Quantitative requirements can be set for renewable fuel infrastructure (cars, renewable equipment etc.) or for the biofuel itself. Quantitative requirements can also be set on the consumption of renewable fuels through an implemented quota obligation scheme. As in the case of distribution support for renewable fuels, a penalty can be applied for non-compliance with the set objectives.

Other support measures

Almost all countries have research and development (R&D) support schemes for renewable fuels. Research on technology improvement and new technologies is currently being pursued through R&D programmes, with a strong emphasis on the commercial development of second-generation biofuels technology.

In order to support the domestic production of biofuels, some countries or regional trading blocs (e.g. the European Union) apply import tariffs on biofuel or on raw materials. These are commonly applied to provide a measure of protection for the domestic production of these agricultural products. In addition to tariffs, other non tariff-barriers are used to support biofuels. Among theses, fuel quality standards set specific requirements for fossil fuels (volatility, blending ratio, etc.) (OECD 2008).

4.3 Energy market reform

Beside of the objectives of energy efficiency and the increased use of renewable energy sources in energy generation, the Czech Energy Strategy Plan includes the objective to reform energy markets. The fourth goal of the State Energy Policy (2004) includes the requirements of full adaptation of the market model of energy sector pursued within the EU (see chapter 2.5.1). The following aspects of energy market reform is linked to a sustainable development of the energy sector with particular relevance:

- The existence of power monopolies
- Unbundling the power sector
- The real costs of nuclear power plants
- Environmental tax reform

The process of liberalizing the power markets, the introduction of competition among power producers and the unbundling of production, transmission and distribution of power are necessary elements of the renewable energy deployment.

Unbundling in the power sector may be advantageous for the deployment of renewable energy use, because it creates more transparency in the power industry.

4.3.1 The real costs of nuclear power plants

Apart from the social dimension of the specific risks of the nuclear cycle – such as danger of major nuclear accidents, storage of radioactive waste, price and availability of nuclear fuel and proliferation – the role of nuclear energy depends on its costs. However, current market prices do not reflect the real costs of this energy.

The real costs of nuclear power plants are not exactly determinable, especially not ex ante (Irrek 2008b). There are several uncertainties and risks during the lifetime of a nuclear power plant of approximately 80 to 180 years from the commissioning to the revitalisation of the site. Therefore the examination of cost-influencing factors, the application of appropriate concepts and the accounting for financial risks becomes more significant.

In order to get the nuclear power economics fair, the following cost factors have to be regarded as significant:

- Investment costs: Manufacturers and operators usually underestimate the real investment costs of nuclear power plants. This has been the case for new nuclear plants of the generation III/III or the EPR in Finland. It is thus not probable that the systematic underestimation of investment costs will change with the fourth generation of nuclear plants.

Table 5: Examples of investment cost underestimations of manufacturers and operators

Nuclear power plant (start of construction)	Originally estimated costs	Real costs	Cost increase
Tarapur III and IV, India (2006)	2,428 Rs Crores	6,200 Rs Crores	+255%
Sizewell B, UK (1987)	1,691 Mio £	3,700 Mio. £	+219%
EPR OL 3 Olkiluoto, Finland (2003)	3.2 Mrd. €	4.5 Mrd. € until now	+41%

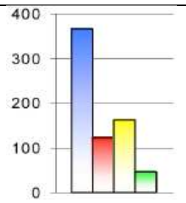
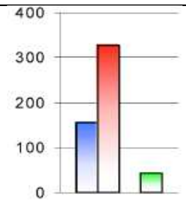
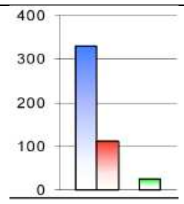
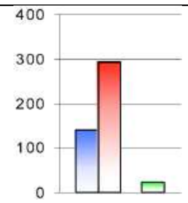
Source: Irrek 2008a.

- Retrofit costs: Expenditures for necessary major maintenances and security retrofit measures occur in practice at different levels and different time periods which are difficult to estimate in advance. These costs are usually caused by unpredictable technical faults or by changes in the official security conditions. Prognos (2008) estimates the typical retrofit costs over the operational lifetime between 0.2 – 0.9 EUR/MW_{el}, while the Wuppertal Institute / Öko-Institute (2000) calculates the retrofit costs to be around 2.4 EUR/MWh_{el}.
- Fuel costs („Front-end“): The share of fuel costs amounts to approximately 12% of the total costs of the nuclear power plant according to Prognos (2008). The share of the uranium obtaining amounts to 5% of the total costs (without the external costs of the uranium extraction e. g. health consequences for the miners) Prognos (2008) estimates the nuclear fuel obtaining costs to be at around 3,9 EUR/MWh, if the price of

uranium amounts to 90 US-$/kg. However, changes of the uranium prices cause only small effects on the total costs per MWh.

- Personnel costs: Newer nuclear power plants require less own staff than existing ones. On the other hand the importance of external specialist (e. g. security staff) is increasing. Table 6 gives an overview on the number of employees at Würgassen nuclear power plant over time. 5 years after closure the number of own personnel dropped significantly while the need for external experts increased. The total number of job positions almost halved since 1994.

Table 6: Job positions in Würgassen nuclear power plant 1994 / 2001

	Job positions depending on the nuclear power plant		Employees with residence within a radius of 20 km	
	Power operation (1994)	Deconstruction, 5 years after closure (2001)	Power operation (1994)	Deconstruction, 5 years after closure (2001)
Own personal External personal External personal for revision Other contracts				
Sum of direct job positions	700	530	466	456
Sum of indirect job positions	700	530	308	301
Sum	1400	1060	774	757

Source: Irrek 2008a.

- Insurance costs: The liability of nuclear power plant operators for a worst possible accident is very limited. Nuclear power plants are remarkably under-insured; the general public takes the remaining risk. Consequently, the insurance costs of the operators are relatively small compared to the real costs in a worst possible accident case. The financial analysts have not taken into account this type of costs until now. The liability insurance for nuclear power plants was at 0.09 EUR/MWh in 2007 in Germany, while the total private insurance costs of a typical EDF power plant would amount to 53 EUR/MWh according to Leurs and Wit (2003).
- Costs of nuclear waste disposal, closure and revitalisation: Although the estimations of nuclear plant closure costs are getting more precise, it is hard to make reliable assumptions about revitalization costs (including the costs of nuclear waste disposal) because of the missing experience and information about permanent disposal sites for radioactive waste. The costs vary according to different concepts and ways of disposal, the amount of radioactive waste, temperature of the fuel elements, geological circumstances, used containers and raw material prices (e. g. steel).
- Variable operating costs: Both the costs of maintenance, repair and revision and the variable costs of auxiliary materials etc. belong to the variable operating costs. Prognos (2008) estimates the fixed operating costs between 41 – 96 EUR/kW/year, while Wuppertal Institute/Öko-Institute approximated the variable operating costs to 43

EUR/(kW*a). That means approx. 5,7 EUR/MWh_{el} capacity-related and further 0,8 EUR/MWh_{el} variable operating costs. Total variable operating costs amount to 6,5 $EUR/MWh_{el.}$

- Revisions costs: Nuclear power plant operators have tendentiously underestimated the duration of revisions in the past. Nevertheless the operators succeeded in reducing the duration of revisions during the last few years as a consequence of the cost pressure on the liberalized market.
- There are several other costs, such as the state support expenditures for research and development in the nuclear industry. These were not considered as cost factors in the nuclear sector. Therefore the calculations for the price of electricity from nuclear sources ignore these expenditures.

According to Irrek (2008b) the crucial economic parameters of operating a nuclear plant are the utilization level of the nuclear power plant, the burnout of nuclear fuel elements and particularly the insurance costs of the power plant. New power plant investments and retrofits depend mainly on the expected lifetime and the amount of invested interest on capital. Furthermore the incalculable risks of nuclear power plant closure, revitalization and nuclear waste disposal amount to this. Therefore electricity production costs in new nuclear power plants range between 19.2 to 80.8 EUR/MWh for example in Switzerland. The Keystone-report (2007) estimates these electricity production costs between 62.5 and 83.6 EUR/MWh in the United States. Schneckenburger (2008) calculates electricity generation costs of 62.4 EUR/MWh in 2008 while they will be 65.5 EUR/MWh in 2016 (Irrek 2008b).

Producers and operators are of course interested in reduction of financial risks and external or internal state support. This can cover the insurance costs of the nuclear power plant, the limited liability of operators and producers, the co-financing of nuclear waste disposal, closure and revitalization or preferential building loans.

The profitability of a nuclear power plant depends ultimately on the political and legal framework conditions. Nevertheless, the implicit support for nuclear power is quite high in comparison to other means of power production. This should be reduced gradually in the future in order to ensure fair competition on the energy market.

4.3.2 Environmental tax reform

Environmental taxes mean such tax payments that are directly related to the measurement (or estimation) of the environmental pollution caused by the taxpayer. The aim of environmental tax instruments is to improve the environment by pricing its various uses. In the case of pollution, the purpose of the tax instruments is to reduce the level of harmful emissions generated by industrial production processes or consumption. On the other hand environmental tax instruments include specific taxes and charges, tax allowances and tax differentials between products where the most environmentally friendly product is less taxed. As a consequence energy efficiency investments or renewable energy projects become more attractive and furthermore the environmental tax reform can play an important role in creating supportive framework conditions for climate protection strategies (Wuppertal Institute 2005).

The Environmental Tax Reform (ETR) is based on introducing or increasing environmental taxes on carbon products, energy or resource use, while decreasing other distortional taxes, such as labour or social security. Environmental fiscal reform encompasses all environmental tax reforms, subsidies, grants and other environmental incentives as well as the removal of harmful subsidies.

The ETR has two main principles:

- Fiscal neutrality: the general underlying principle is to shift taxation from economic „goods“ such as labour to environmental “bads” such as air pollution.
- Double dividend: Carbon taxes can create a double dividend. This means that on the one hand, economic taxes may have a positive impact on the economic growth and employment, while on the other hand the reduction of carbon emission may decrease local pollution as well.

From the economic point of view, the ETR makes it possible to reach “an optimal level of pollution” under specific conditions concerning its rate and base. This means that energy savings and pollution reduction can be realized in sectors where costs are the lowest (OECD 1996; Energy Policy 2006). The concept has been successfully implemented in several EU member states leading to significant energy savings in Germany, UK, Denmark and the Netherlands.

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