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The Role of Electricity

Energy Modelling and Scenarios

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Athens, 20 March 2007

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Introduction

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1. Preliminaries

The Baseline scenario built for the "Role of Electricity" study was based on assumptions that differ from a similar Baseline scenario built in late 2005 for EC DG TREN. For the present study, the database on technical and economic characteristics of future power generation technologies and end-use electrical equipment have been fully revised to reflect the data proposed by the two other parts of the study, namely the "Demand Block" and the "Supply Block" of the project. In addition, several other updates have been made on data and assumptions, in particular regarding fossil fuel prices which affect the short term projections.

Therefore, the Baseline scenario presented hereinafter is not comparable to the Baseline scenario published by EC DG TREN.

2. Methodology

2.1. Overview of Methodology

The aim of the modelling work carried out within the *Role of Electricity* project was to quantify long-term scenarios for the future evolution of the energy demand and supply sectors in Europe. For this purpose, the PRIMES energy system model has been applied to provide detailed projections up to 2030 and the Prometheus world energy model to perform consistency analysis of world energy markets and longer-term projections up to 2050.

The projections based on the PRIMES model were carried out with a high level of detail, on a country-by-country basis for all current and potential future members of the European Union (in total 30 countries). This report shows only aggregate results for the EU-25.

The Prometheus model has analysed endogenously the formation of world energy prices. It treats Europe as a single region but views it as part of a global, worldwide energy system and market. The Prometheus model implements a method of stochastic simulation. For the construction of scenarios within the current project, the deterministic version of the model was used, in which version exogenous parameters take values for the future that are considered to be known with certainty.

The databases of both models have been considerably updated and supplemented with data and information provided by the other two teams working on the supply- and demand-side sections of the project, applying a bottom-up approach. These teams provided technical and economic estimates of the future evolution of technologies related to power generation and consumers' use of electricity.

A *scenario* is composed of a set of assumptions and the consequent results of these assumptions worked out through the model. The energy system models start by taking as given a future path of economic growth and then focus on energy demand and supply and the interactions between them that influence the formation of energy market prices. The models do not however take into account any feedback effects from energy on overall economic growth.

The *models* represent multiple economic sectors and multiple energy forms, commodities and markets. They also represent specific energy technologies in an explicit manner. The future evolution of energy technologies is represented dynamically by taking into account that their technical and economic features evolve over time and are influenced by the degree to which they penetrate the markets. The potential of all technologies and energy forms or resources is represented as non-linear functions which express possible diminishing returns, possible exhaustion of potential or, on the other hand, positive externalities such as learning by doing.

The *Prometheus model* determines endogenously the future evolution of world fossil-fuel prices as a result of resource potential and the dynamic interactions between demand and supply. The *PRIMES model* takes the world fossil-fuel prices as given and focusses on energy-conversion markets in Europe, such as the electricity market, for which it determines market equilibrium prices endogenously. The projections of the two models are linked together through a model-calibration procedure, which ensures consistency in the combined use of the models.

Both models calculate emissions of pollutants and greenhouse gases from energy conversion and energy use. Policy instruments for emissions-abatement are also represented, including emissions caps, taxes and trading of emission allowances. Similarly, a series of energy-related policy instruments are represented, including energy efficiency and technology standards, taxes and subsidies, support schemes for renewable energy sources and cogeneration, etc.

As is standard practice, the models are first used to quantify a *Baseline scenario* and then to quantify alternative policy-oriented scenarios. The baseline scenario serves as a reference against which the alternative scenarios are assessed. This procedure serves to evaluate the implications and cost-effectiveness of the policies and measures that are reflected in the assumptions for the alternative scenarios.

2.2. The PRIMES model

The PRIMES model simulates a market equilibrium solution for energy supply and demand. The model determines the equilibrium by finding the prices of each energy form such that the quantity producers find best to supply matches the quantity consumers wish to use. The model is behavioural but it also represents in an explicit and detailed manner the available energy demand and supply technologies and pollution abatement technologies. The system reflects considerations about market economics, industry structure, energy/environmental policies and regulation. These are conceived so as to influence market behaviour of energy system agents. The modular structure of PRIMES reflects a distribution of decision making among agents (sectors and sub-sectors) that decide individually about their supply, demand, combined supply and demand, and prices. The market integrating part of PRIMES simulates market clearing.

The model is organised by energy production sub-systems (oil products, natural gas, coal, electricity and heat production, others) for supply and by end-use sectors for demand (residential, commercial, transport, nine industrial sectors). Some demanders may be also suppliers, as for example industrial co-generators of electricity and steam.

Several end-uses and processes are distinguished: a) 12 industrial sectors, subdivided into 26 sub-sectors using energy in 12 generic processes (e.g. air compression, furnaces); b) 5 tertiary sectors, using energy in 6 processes (air conditioning, office equipment); c) 4 dwelling types using energy in 5 processes and 12 types of electrical durable goods (e.g. refrigerator, washing machine, television); d) 4 transport modes, 10 transport means and 10 vehicle technologies, 14 fossil fuel types, 4 new fuel carriers (e.g. hydrogen, methanol, bio-fuels) 10 renewable energy types, e) several supply sub-systems: power and steam generation, refineries, gas supply, biomass supply, hydrogen supply (not used in this project), primary energy production. The power generation sub-model represents 150 power and steam technologies, the electricity grid with import and export links in the EU internal energy market and details of load curves (typical days and hours) for electricity and steam; f) 7 types of pollutants emitted from energy processes and a series of associated policy instruments, including emission trading schemes.

The PRIMES model fully covers 34 actual, associated or potential EU member-states. The simulations for the current project concerned 30 countries (25 EU members plus Bulgaria, Romania, Turkey, Norway and Switzerland). In this report only aggregated results for EU-25 are presented. Results by country and for all 30 countries are available upon request.

The model's database includes historical data, on which the model is calibrated. This concerns electricity demand data, electricity price data and detailed data on existing power plants and their use. The present database covers 1990-2000 and 2000 to 2005. The model produces results for 2000 and 2005 as calibrated years. Results for year 2010 and beyond (up to 2030, 2050) are considered as projections (scenario years).

Exogenous to PRIMES are: GDP growth, industrial activity per sector, world fossil fuel prices, energy and environment taxes and other parameters of policies, power plants and infrastructures that are known to be under construction in base year, baseline energy technology progress. Results from PRIMES are time series on: energy demand, supply and balances, energy prices, energy investment and emissions for 34 European countries.

2.3. Methodology regarding emission reduction

The alternative scenarios are constrained by obligation to reduce carbon dioxide emissions. The cap on emissions is defined for the EU25 taken as a whole and is equally applied to all alternative scenarios. The models determine an economically optimal allocation of carbon abatement effort among sectors and countries by taking into account a variety of technical and resource constraints. Hence the scenarios suggest changes in energy demand and supply patterns.

To meet the overall emissions constraint, all demanders and suppliers consider the marginal abatement cost associated with the emissions constraint as a cost factor. So carbon intensive energy forms become more expensive than others. The PRIMES and the Prometheus models simulate how demanders for energy and suppliers modify their demand and supply behaviour in order to shift away from carbon intensive energy forms, incurring the least possible cost.

Energy demanders solve a problem of utility maximization under income constraint (residential and transport consumers) or a problem of production cost minimization under output production constraint (industrial and tertiary consumers). In both problems, the aim is to determine the optimal purchase of commodities or production factors. The model considers that this choice is made over time in a dynamic way, involving not only the choice of commodities that are consumed but also the choice of technology and investment in end-use devices, processes and appliances, including investment favouring energy efficiency and energy saving. As a result of these decisions by sector, total demand for energy and the fuel mix in their consumption change.

The producers of energy, like power generators, adapt their supply behaviour to meet the modified level of demand and optimise their cost. The latter is affected by the carbon-induced changes in the relative costs of energy forms that are used as inputs to their energy conversion processes. The optimisation is considered to be dynamic over time. It involves choice of technologies and investment in new energy production processes. Energy producers adapt their choices of technology for investment and the mix of energy inputs, and they redefine their supply prices in order to recover increasing costs of adaptation to the emission constraints. It is assumed that in doing so the energy producers apply a Ramsey-Boiteux pricing policy: they determine a level of prices that on average allow them to fully recover all kinds of costs, including fixed and stranded costs; the same methodology is followed to determine tariffs by consumer category reflecting their varying price elasticities of demand.

As a result of emission restriction, energy commodities' prices change. Demanders further respond by adapting their demand behaviour. An iterative cycle is thus taking place until market equilibrium is reached. A similar process takes place when imposing an energy tax. The notable difference between a carbon value and the energy tax is that the energy tax affects income of consumers because it implies transfer of money from consumers to the State. Therefore, by reducing available income, the energy tax directly affects energy demand. On the contrary the carbon value only affects relative costs and only induces indirect increases of energy costs.

In the presence of an overall constraint on carbon emissions, demanders and suppliers of energy have a series of means to reduce carbon emissions. These means can be classified in the following categories:

1. *Energy Efficiency*: Reduction of overall energy consumption as a result of energy saving investment and rational use of energy; also choice of end-use process technologies and appliances which have higher energy efficiency, i.e. energy consumption per unit of useful energy; cogeneration of heat and power and also advanced heat pump applications involving recovery of renewable heat.

2. *Change of fossil fuel mix*: Shift in favour of natural gas and away from carbon intensive fossil fuels, notably coal and lignite.

3. *Renewables*: Higher investment and use of renewables both in demand and supply sectors, since renewables are all considered as carbon free resources.

4. *Nuclear energy*: Higher investment in nuclear power, since nuclear is a carbon free source for power generation; the treatment of nuclear fuel is energy intensive but the net effect on carbon emissions is clearly negative.

5. *Carbon capture and storage (CCS)*: Applicable on power generation plants burning fossil fuels. Carbon capture reduces the thermal efficiency of the plant. The captured CO2 is transported to specific sites where it can be stored underground for an undetermined period of time. Since CO2 is not emitted to the atmosphere, CCS is considered as a carbon free technology (for the part corresponding to net contribution to CO2 emission reduction).

For different technical and economic reasons, all means of CO2 emission reduction have limited potential. Incremental costs occur as they further increase in volume. Beyond such scale, incremental costs incur as they further increase in volume. Beyond a certain scale, these costs are higher than decreasing costs resulting from learning by doing. Therefore, a long-term cost supply curve with increasing slope is associated with the deployment of carbon reducing means.

Since the energy system has to deliver lower emissions and since all emission reduction means have an increasing marginal cost curve, the optimal mix of means to meet the emission constraint has to follow the rule of equality of marginal abatement costs across all means. In other words, every mean must be used up to the volume to which marginal abatement cost is the same for all means.

If any of the above emission reduction means is not allowed to be used because of some policy or technical reasons, then total cost of emission reduction increases as compared with a case in which such reduction means is available. The absence of some of the carbon reduction means implies that other means have to be used at higher scale in order to meet the same emission reduction. Since all means exhibit increasing marginal costs, in other terms diminishing returns, total cost also increases.

It is also possible that for different policy or institutional reasons the baseline scenario may not represent a fully optimised energy system. This may be due to distortions which may be assumed to persist in the baseline scenario. In this case, there is an opportunity to improve the cost of energy if the distortions that lead to non optimality were removed. For the current baseline scenario for the EU25 at least three categories of distortion are identified.

The first category includes the distortions that prevent full exploitation of the energy efficiency potential. This is often termed the "efficiency gap". There exist certain possibilities to improve energy efficiency which are economically beneficial, but which are not fully exploited in the baseline scenario. An example is energy efficient lighting for which economic calculations suggest that the pay back period can be below one or two years. However, the baseline trends do not show full exploitation of efficiency in lighting. There are two contrasted interpretations concerning the efficiency gap: one interpretation considers that this efficiency gap is not a distortion but is rather due to a subjective discount rate, as effectively considered by decision makers, which happens to be very high for certain consumers and for households in particular. This point of view implies that there is always a positive non-zero cost associated with efficiency gains. The second interpretation considers that institutional and information distortions exist: they are qualified as non-market "barriers". These barriers could be removed as a result of adequate policy, so as to enable negative (profit) costs for the consumer. The PRIMES model retains a mixed approach regarding the efficiency gap issue.

The model recognises that the process of efficiency improvement is slow and may not lead to complete exploitation of potential. The slowness is attributed to several reasons: inertia due to persisting consumers' habits; existing stock of relatively inefficient end-use equipment with slow replacement rate; high subjective discount rates (PRIMES uses discount rates up to 25% for certain consumers, which however are considerably smaller than subjective discount rates that have been proposed in the literature and suggested by econometric studies); barriers related to lack of information and experience with new and advanced end-user technologies (learning by doing is one of the mechanisms represented in the model).

The PRIMES model includes mechanisms which involve exogenous parameters to influence the degree of inertia of consumers in adopting advanced technologies and in pursuing energy efficiency behaviour. The model represents the degree of market acceptance and confidence attributed to new technologies, as well as the degree of awareness and sensitivity of consumers regarding energy efficiency and rational use of energy. These parameters are linked with scenario assumptions and may change in proportion to the degree of stringency of environmental constraints assumed for each scenario.

For the scenarios quantified in the context of the present study, the mechanism of acceleration of energy efficiency is activated only in two of the alternative scenarios, namely the "*Role of Electricity*" and the "*Efficiency & RES*" scenarios. For all other scenarios, it is assumed that the inertia and behaviour with respect to barriers and lack of acceptance of advanced end-use technologies remain the same as in the Baseline scenario.

The second category concerns the distortions that may prevent high exploitation of the potential of renewables. The deployment of power or heat production from renewable sources is by nature very dispersed and decentralised. This deployment is therefore confronted with several obstacles and barriers which are related to non-energy policies and various institutional regimes, such as land use, basic infrastructure in remote areas, architectural and urban constraints, agricultural policy, etc. For example, it has been observed that lack of information and other barriers induce low acceptance of renewable plants by small communities. The PRIMES model includes exogenous parameters that enable partial removal of those barriers. The removal of barriers is equivalent to a shift of the cost-supply curve of renewables to the right allowing for higher potential for equal unit cost. Acceleration of deployment of renewables is simulated by changing their values in proportion to the degree of stringency of environmental constraints. Regarding non-biomass renewables, this mechanism is activated only for some of the alternative scenarios.

The third category of distortions concerns nuclear energy. In the baseline scenario it is assumed that, because of general policy considerations, restrictions apply on nuclear energy: nuclear phase out is followed in three member-states and premature decommissioning of nuclear capacity takes place according to an announced time schedule; extension of life time of old nuclear plants, where this is possible, does not take place in the Baseline; nuclear energy does not develop in ten member-states where nuclear has not been used in the past. In economic terms, these restrictions are partly non optimal. For example, according to engineering studies, the life time of some of the old nuclear plants can be extended at low investment cost and without safety risks. If this option was taken, then electricity generation costs could be lower than in baseline. The option of extending the life time of old nuclear plants is considered in some of the scenarios of the study, and these scenarios involve cancelling of nuclear phase out in three member states. This implies that, at least as a result of the absence of premature decommissioning of nuclear plant, the cost of electricity supply, *ceteris paribus*, will be lower in these scenarios than in baseline.

All alternative scenarios assume the imposition of an overall cap on carbon dioxide emissions from energy demand and supply. The PRIMES and Prometheus models determined endogenously the carbon value needed to meet this constraint.

Baseline Scenario

Update end 2006

3. Main Assumptions for Baseline Scenario

The Baseline scenario is a projection of future evolution of the European energy demand and supply system reflecting business-as-usual trends. The scenario does not project a frozen system: dynamic trends and changes are reflected in this scenario. The evolution is considered as an outcome of market forces without taking into account external or societal costs, as for example the environmental impacts and the eventual threats with respect to security of energy supply. For the Baseline scenario, it is assumed that future changes are only influenced by policies and measures adopted in the past: no additional policy instruments or policy targets are assumed for this scenario.

The Baseline scenario is not a forecast, but only a simulation of what the limitations of the system would be if evolution just continued from past without consideration for market failures or adverse effects. The Baseline scenario is essentially a least cost projection of future energy system without consideration for environmental costs and impacts. Effects related to global warming or the geopolitical risks affecting security of energy supply are assumed for the Baseline scenario to be neglected by economic agents. In particular, the Baseline scenario does not include policies to reduce greenhouse gases in view of the Kyoto commitments. All the same, no attempt has been made to forecast how Europe might endeavour to fulfil the Kyoto or post-Kyoto commitments. In addition, the Baseline scenario ignores the implications from increasing the volume of geopolitically sensitive imports, namely imports of oil and natural gas.

The Baseline scenario does not involve freezing energy efficiency progress or no penetration of new technologies and renewables. On the contrary, policies promoting energy efficiency as adopted in the past, but also market trends that lead to energy productivity improvement, lead to improvement in terms of energy intensity in all sectors of the economy. However, contrary to alternative scenarios, the Baseline scenario only includes policies, standards and measures that have been put in place before 2004. So, energy efficiency and productivity gains are driven by the aim of minimizing costs and maximizing economic benefits without any reference to possible benefits from further environmental improvement.

Similarly, renewables and CHP development is driven, within the Baseline, by private economic considerations taking into account the supportive policies which are assumed to apply in short and medium term but discontinue in the long term. Therefore market forces and least cost supply drive the development of renewables and cogeneration of heat and power.

Table 1: Baseline Scenario – Assumptions about Nuclear Energy

Nuclear Phase-out

GW installed	2000	2005	2010	2015	2020	2025	2030
Belgium	6.03	6.08	6.08	5.24	4.22	2.17	0
Germany	23.67	20.96	19.73	13.67	5.52	0	0
Sweden	9.82	9.82	9.82	6.93	4.97	0.61	0

No Nuclear Power:
Austria, Cyprus, Denmark, Estonia, Greece, Italy, Ireland Latvia, Luxembourg, Malta, Portugal, Norway

Possible Nuclear Investment but no extension of lifetime of old plants:
Bulgaria, Czech, France, Finland, Hungary, Lithuania, Poland, Romania, Slovakia, Slovenia, Spain, Switzerland, UK

It is assumed that the Baseline scenario does not address Kyoto and post-Kyoto objectives. However, for this scenario it is assumed that the current ETS system continues to operate and that it balances at low prices of emission allowances. This reflects absence of further pursuing climate policy measures in the European Union. It is thus assumed that the ETS system induces a constant Carbon Value of 5€/tCO_2 which is applied as an opportunity cost on all uses of fossil fuels in proportion to their emission of CO_2. This level of Carbon Value is not enough to meet the Kyoto CO_2 target of limiting emissions between 2008 and 2012 at a level of -8% from their level in base year, i.e. 1990, and it is far lower from a level that would induce emission curbing during the post-Kyoto time period.

For the Baseline scenario it is assumed that current policies regarding electricity generation from nuclear energy are realized in the long term. This implies that the announced nuclear phase-out in Belgium, Germany and Sweden is implemented. Also, it is assumed that eleven other member-states do not develop nuclear energy, but the remaining member-states may invest in new nuclear plants. However, it is assumed that extension of lifetime of nuclear plants does not take place. The restrictions on the development of nuclear energy as assumed for the Baseline scenario are shown in Table 1.

The Baseline scenario takes into account the prevailing perception that the high level of oil and gas prices, as observed in the past two years, will persist in the future. This view is very different from perceptions prevailing before 2004[1]. For the current Baseline, the world prices of oil and gas are projected to stabilise in the short term slightly below current levels and then increase smoothly reaching 46 €'2005/bbl by 2030 and 80 €'2005/bbl by 2050[2]. These long term oil price trends reflect resource constraints, continuous growth of global energy demand and increasing dependence on non conventional oil, which is associated with high extraction costs.

Natural gas prices are projected to continue to be tightly linked with oil prices. This view is taken not only because existing long term gas procurement contracts index gas prices to oil, but also because market dynamics justify persistence of this linkage in the long term. Natural gas is potentially a substitute to oil, the demand for gas is expected to rise worldwide and its cost-supply relationship reflects highly increasing marginal costs.

Coal prices are projected to rise at far lower rates than oil and gas as a result of high coal resources and more favourable geopolitics. This implies that the competitiveness of gas vis-à-vis coal steadily deteriorates: the gas to coal price ratio, from 1.5 in the 90s and 2.5 in 2006, approaches 3 before 2030 and then reaches the level of 5 in 2050.

The relationships between world energy demand, fossil fuel resources and world energy prices have been analysed by using the Prometheus[3] stochastic world energy model. The model ensures consistency of world energy developments and the assumed trajectory of energy prices. The price scenario used for the Baseline scenario reflects the median of the Prometheus stochastic analysis of future energy prices.

The basic scenario by the Prometheus model reflects a world economic activity that steadily grows at a rate of 3% per year until 2030 and then by 2.2% in the period 2030 to 2050. It was found that year 2012 is likely to be a turning point as emerging economies, such as China and India, will start consuming higher volumes of energy than the OECD. Although, the Prometheus model projects energy supply to be based on a relatively sufficient resource basis to cover growing demand, growing demand combined with highly increasing marginal cost of supply, particularly beyond 2030, explain the upward trend of oil and gas prices.

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[1] The Baseline scenario constructed in late 2003 was projecting world oil and gas prices to reach in 2030 the levels of 25 €'2005 per barrel and a gas price of less than 3.8 €'2005 per MBTU. For the current Baseline the levels projected are almost double (46 €'2005/bbl for oil and 6.85 €'2005 per MBTU).

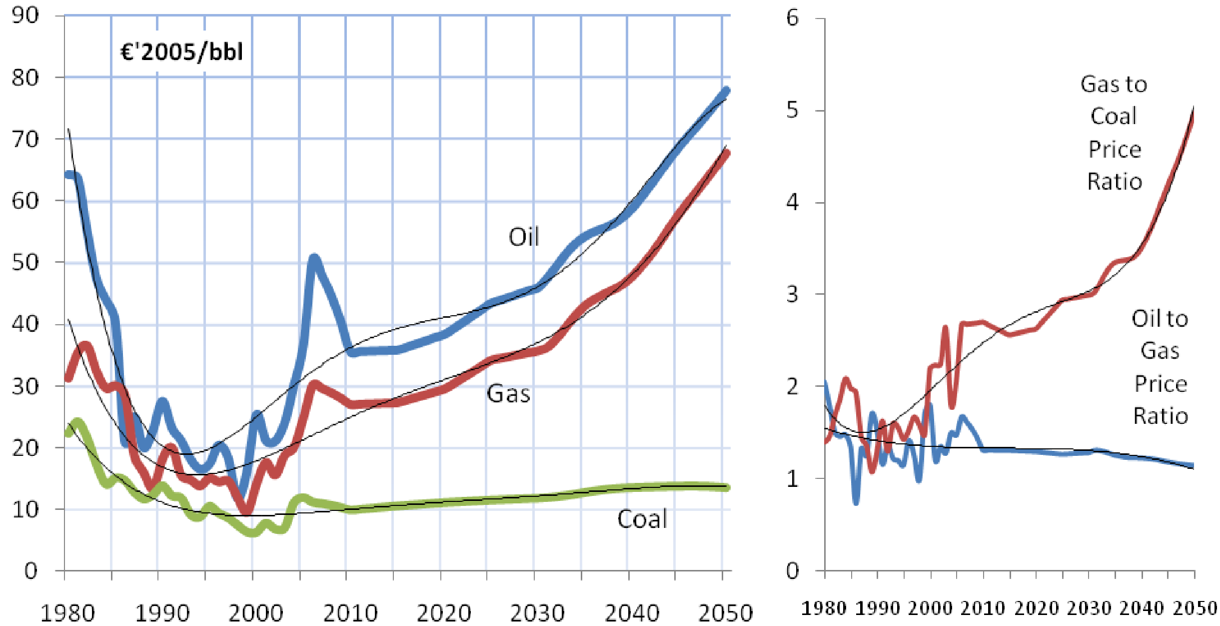
[2] All monetary values are given in Euros of 2005 in constant terms (without inflation).

[3] The Prometheus model has been developed at E3MLab of ICCS/NTUA and has been extensively supported by the EC DG Res.

Figure 1 shows the projection of average prices of fossil fuels imported in Europe and compares with historical statistics updated up to 2006. The same graph shows the continuous decline of competitiveness of gas vis-à-vis coal, a trend which is expected to influence future investment choices for power generation. The gas to oil price ratio is projected to be stable before 2030 and slightly increase beyond 2030.

For the PRIMES model, which studied the period up to 2030, the above mentioned price trajectories are assumed to remain unchanged[4] for all alternative scenarios.

Figure 1: Import prices of Hydrocarbons to Europe



Forecasting future energy prices is very uncertain, therefore in addition high price scenarios were developed. For these scenarios, high prices concerned both the high prices Baseline and the high-prices alternative scenarios. The high prices scenarios served to perform sensitivity analysis.

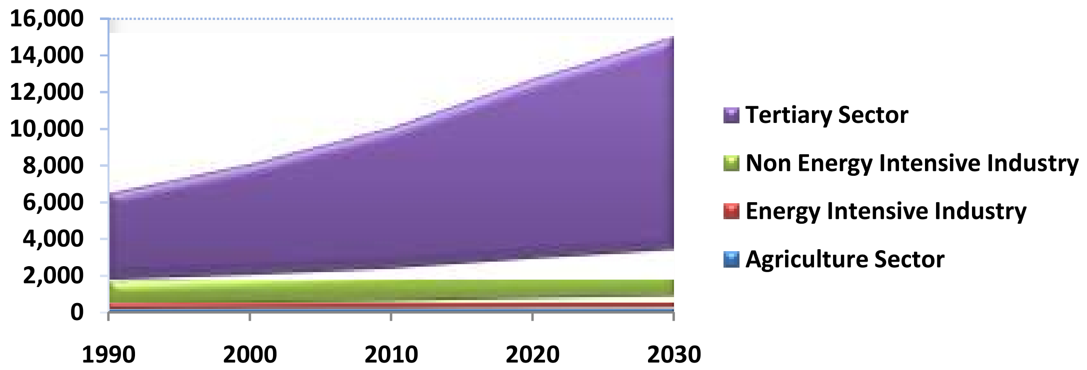
The economic growth projection underlying the Baseline scenario for energy is optimistic. European economy is projected to steadily grow at an average rate of 2% per year until 2030. It is assumed that in the longer term, beyond 2030, European growth slows down approaching 1% per year until 2050. The European economy progressively changes its structure as sectors with higher value added develop more rapidly than sectors with heavy intensiveness with respect to energy and materials.

[4] The Prometheus model representing world energy prices as endogenous variables involves different trajectories of fossil fuel prices for each scenario.

European demographics are projected to be rather stable throughout the projection period. Although total population is not projected to increase, societal changes drive an increase of the number of households (by 1% per year in the short term and by 0.5%per year in the long term). Despite the resulting decline of the average size of households, increasing total number of households imply higher total energy needs for the residential sector.

Table 2: Economic Growth Scenario for EU-25

	1990	2000	2010	2020	2030	Annual Growth 1990-2000	2000-2010	2010-2020	2020-2030
GDP of EU-25 (in 000 M€ '05)	8002	9815	12009	14981	17608	2.06	2.04	2.24	1.63
Value Added in Factor Prices (in 000 M€ '05)									
Energy Intensive Industry	354	417	499	618	717	1.64	1.81	2.17	1.51
Non Energy Intensive Industry	1247	1432	1667	2075	2424	1.39	1.53	2.21	1.57
Tertiary Sector	4678	6005	7658	9733	11573	2.53	2.46	2.43	1.75
Agriculture Sector	216	243	252	277	295	1.16	0.37	0.96	0.63
Consumer Expenditure (€/capita)	10589	12575	14958	18287	21417	1.73	1.75	2.03	1.59
Population (million)	441	453	464	469	469	0.27	0.24	0.11	0.00
Passenger transport activity (Gpkm)	4641	5466	6450	7403	8132	1.65	1.67	1.39	0.94
Freight transport activity (Gtkm)	1754	2132	2583	3050	3433	1.97	1.94	1.68	1.19



The projections of transport activity has been provided to PRIMES model by the model SCENES which is specialised in transport planning. The transport scenario, which is detailed in terms of flows of transportation activities between and within the EU countries, shows a certain decoupling of the growth of transportation activity from GDP growth. This trend, which is more accentuated in the long term, is a combined result of productivity gains and saturation effects.

The economic growth assumptions show that the services sector gradually dominates the European economy. This has considerable implications for energy, since this sector consumes energy in buildings, has intensive uses of electricity and the energy related expenses represent a small share in total production costs.

For the time period beyond 2030, the economic projection involves GDP growth of 1% per year, slight decline of population (by 0.06% per year) and further slow-down of the increase in transportation activity. As an example, the ratio of number of cars per capita, which is assumed to grow by 1.2% per year in the period 2005 to 2030, is projected to reduce to 0.23% per year in the period 2030 to 2050.

The economic growth projection (see Table 2) is assumed to be unchanged for all scenarios quantified with the models.

4. Discussion of Results for Baseline Scenario

4.1. Total Primary Energy Requirements

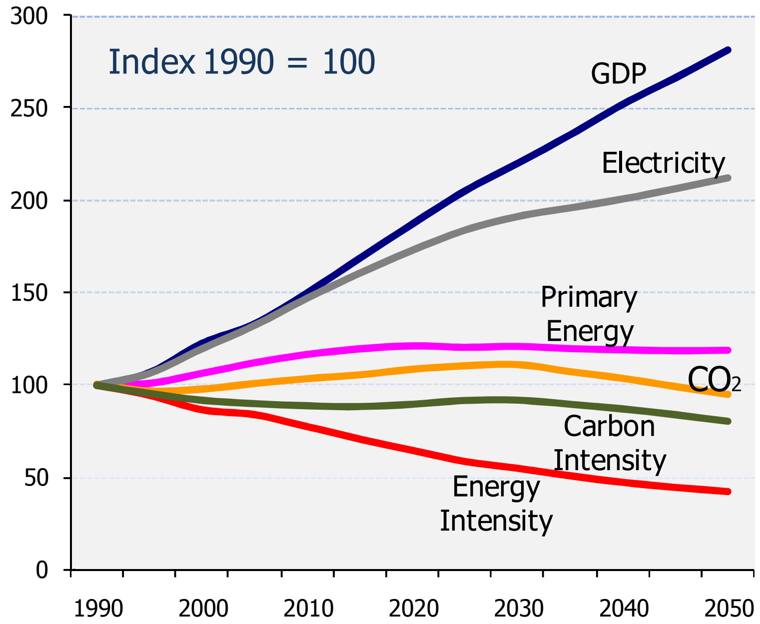
The results of the Baseline scenario for the "Role of Electricity" study show that, despite the evidence of relative saturation for certain energy uses in the EU-25, energy demand is likely to continue to grow, albeit at rates significantly lower than those experienced in the recent past. Decoupling energy requirements from economic growth is a persisting trend observed since late 70s. The energy efficiency improvement within a business-as-usual perspective is a combined effect of structural changes in the economy, saturation and technology progress.

Total primary energy requirements of the EU-25 are projected to increase at an annual rate of 0.3% from 2005 to 2030 compared to an annual growth rate of 2 % for GDP. The rate of increase of total energy requirements was 0.6% per year during the decade 1990 to 2000, is projected to increase at 0.9% per year in 2000-2010 and then to slow down at a level of 0.4% per year in 2010-2020 and stabilise at 0% per year on average during the decade 2020-2030. The Baseline scenario projects that the factors driving energy productivity improvement lead to a gradual decline of total primary energy requirements of Europe during the period beyond 2030. Total energy requirements decrease by 0.4% per year on average during the period 2030 to 2050 and attain a level in 2050 which is lower than 2030 by 9%.

The decoupling of energy from economic growth can be measured by the energy intensity index which is defined as the ratio between total primary energy requirements and GDP in real terms. During the 90s, the energy intensity index (for the EU-25) was observed to decline at an average rate of 1.4% per year. The Baseline projection shows a slow down at -1.1% per year during the period 2000-2010 and a further decline at an average pace of -1.7% per year until 2030. The projection beyond 2030 also shows a continuous decline of energy intensity at an average rate of 1.6% per year.

The main reasons that justify this significant decline in energy intensity for the Baseline scenario include: a) changes in the structure of EU economy which shifts away from energy intensive processes and towards high value added services and commodities; b) improvements in energy productivity driven by technology progress which takes place both in demand and in energy supply sectors; c) saturation in demand for some intensive energy uses, particularly in transportation in the long term and mainly beyond 2030.

Figure 2: Baseline Scenario for EU25 - Main Indicators

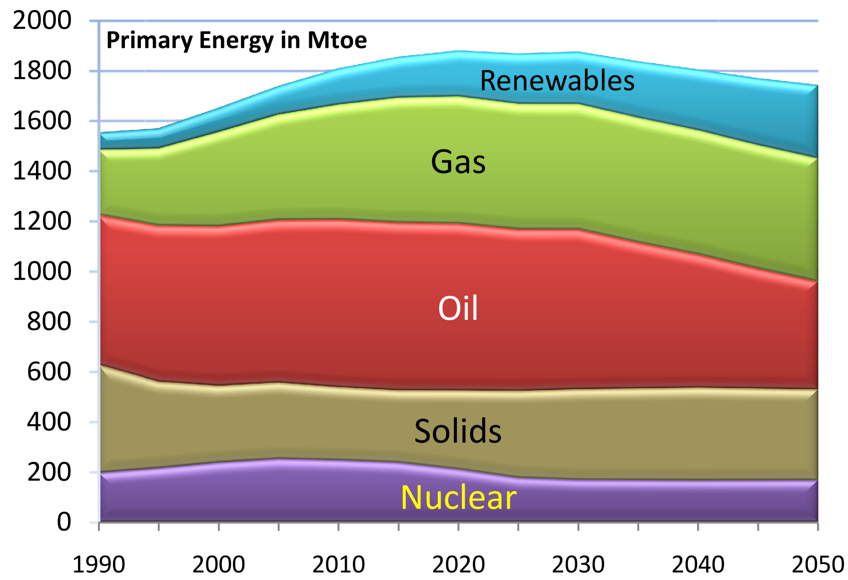


The energy intensity improvement trend is in line with observed statistics over the long period post oil crisis of 1973. The slow down of this decoupling during the recent years must be attributed to the slow down of GDP growth which as usually is accompanied with slow down of technology progress. The projection to 2030 for the Baseline scenario shows a slight acceleration of the decoupling of energy consumption from GDP growth, as compared to past trends, a trend which is also attributed to the assumption that oil and gas prices are likely to follow an increasing pace throughout the projection horizon.

Renewable energy forms are projected to remain the fastest growing energy forms in the EU-25 energy system, as was the case over the last few years. Renewable energy forms are projected to grow at a remarkable rate: +2.44% per year on average in 2005-2030 and 4.1% per year in the decade 2000-2010. This trend is partly due to the supportive policies for renewables but also is an outcome of economic considerations given that power from renewables, particularly the wind power, displays increasing economic competitiveness over time. Biomass is also likely to develop as a result of policies imposing a certain share of bio-fuels in automotive fuel supply and the increasing use of biomass and waste in certain niche market applications, particularly in CHP.

Over the last ten years, the use of natural gas showed remarkable growth in all sectors driven by environmental and comfort concerns but also as a result of low gas supply prices which persisted until 2003. In power generation, the combined cycle technology offered, during the same period, a highly economic and environmentally attractive option for capacity expansion. For these reasons, consumption of gas in final energy uses progressed at an average rate of about 2.5% per year during the last ten years and its use in power generation also increased rapidly, at an average rate of 8% per year in the period 1990-2003.

Figure 3: Baseline Scenario for EU25 - Primary Energy Requirements



Over the past couple of years, however, rapidly increasing gas prices, as driven by oil prices, led to reconsideration of power capacity expansion through combined cycle gas plants. However, several gas power projects are currently under construction, while the concerns related to the environment still persist. This explains why the Baseline medium-term trends (2005-2015) shows that gas needs are likely to grow at rates two times faster than overall energy needs. The projections show however that year 2015 is a turning point regarding gas consumption growth. Beyond 2015, a deceleration of further gas penetration is projected. Beyond 2020 total gas use is projected to decline: for the time period 2020 to 2050, total use of gas in EU-25 is projected to decrease at a steady rate of 1% per year. Despite this decline, the EU-25 is still likely to need in the long term incremental volumes of gas, as compared with gas use in 2005. The incremental needs are of the order of 100 bcm per year, but as it will be explained below incremental needs for gas imports are likely be in the future considerably higher than at present.

Despite high oil prices, the Baseline scenario shows that total energy demand for petroleum products is likely to remain at a high level and to be stable in volume throughout the period until 2030. Oil products tend to be used almost exclusively in specific energy uses (transport and petrochemical). However, because of sustained growth of demand in these sectors, the share of oil in total energy requirements remain considerable and reach 33.9% in 2030 compared to 37.3% in 2005. The Baseline projection for the period beyond 2030 involves gradual decline of energy needs for transportation which, since transport is the main driver of persisting demand for oil products, also involves downwards trends of oil needs for EU-25. In 2050, the EU-25 oil needs are projected to be 30% lower in volume than in 2030, in which time oil needs remain identical to their 2005 volumes.

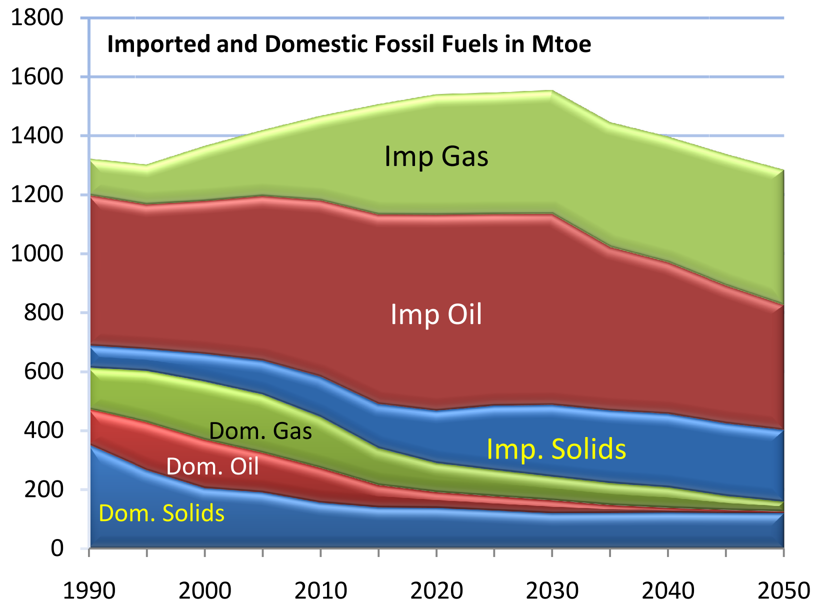
Solid fuels, after experiencing a strong decline in their share during the time period until 2010, are projected to re-establish their market share in the EU-25 energy system and further expand especially in the period beyond 2015. The trajectory of solid fuels use seems to be reciprocal to gas use trajectory. This is due to the fact that, besides certain specific uses of coal in industry which remain rather stable in time, coal and lignite compete mainly against gas in power generation. In the long term and especially beyond 2015, the increasing competitiveness of imported coal drives power expansion through new coal plants. In addition, decommissioning of nuclear plants and phase-out in some countries, which takes place mainly beyond 2025, drives further growth of the use of solid fuels. Primary energy demand for solid fuels is projected to reach in 2030 levels equal to those observed in 2000. For the time period beyond 2030, the Baseline scenario projects stabilisation of the use of solid fuels, which being mainly used in power generation attain a stable share of about 38%.

In the context of the Baseline scenario, the nuclear electricity sector faces four main issues: EU-requirements to close a number of plants in new member states; end of conventional life time of many plants after 2020; nuclear phase out in three EU countries; likely decisions in large nuclear countries not to replace the entire nuclear park after decommissioning. This explains the projected decline in nuclear capacity reaching in 2030 a level which is 40% lower from its current level, despite new nuclear investment of 48 GW. Under Baseline trends, nuclear energy in 2030 is likely to have a share of just 15% in total power generation (30.8% in 2005). The Baseline scenario projects nuclear energy to be restricted to a share of 15% in total power generation in the period beyond 2030 (30.8% in 2005). This implies that in the long term electricity from nuclear energy is likely to be lower by one third from its level in 2005. The gap that represents 8% of total electricity generation in 2030 is likely to be mainly covered by solid fuels, given that solid fuel generation and nuclear compete for base load generation.

4.2. Primary Energy Supply and Energy Imports

Indigenous production of fossil fuels (in EU-25, therefore excluding Norway) is projected to continuously decline over the entire projection period.

Figure 4: Baseline Scenario EU25 - Primary Energy Supply



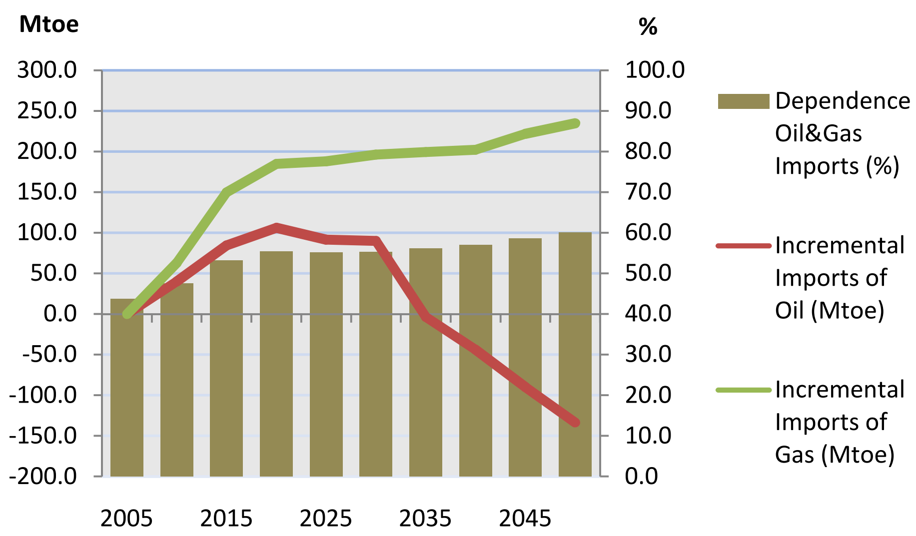
Regarding oil and gas, this trend is a result of gradual depletion of resources in EU-25. It is projected that by 2030 the level of indigenous production of oil and gas will represent 35% for oil and 40% for gas of their level in 2005, a year which roughly correspond to peak indigenous production of oil and gas in the EU-25. The trends beyond 2030 show further decline of indigenous production of oil and gas leading by 2050 to volumes that are almost insignificant in comparison with oil and gas needs of the EU-25.

Increasing primary energy demand for oil and gas and declining primary production in the EU lead together to a considerable increase of dependence of the EU-25 energy system on imports. The overall import dependence indicator, from 50% in 2005, rises to 68% in 2030 and the import dependence on oil and gas, measured by dividing oil and gas imports by total primary energy requirements, from 45% in 2005 rises to 57% in 2030 and becomes higher than 60% in 2050.

The dramatic aggravation of dependence is particularly pronounced for natural gas, for which imports double by 2030 from their level in 2005.

By 2030, the additional gas imports, as compared with the level of imports in 2005, are needed at 40% to cover additional demand for gas and at 60% to replace the lacking indigenous production. The analysis has shown that the incremental gas quantities need mainly to be imported from Russian, Caspian and Middle East areas. Given uncertainties and geopolitical risks the projected incremental needs for gas imports raise concerns regarding long-term security of energy supply.

Figure 5: Baseline Scenario EU25 - Import Dependence



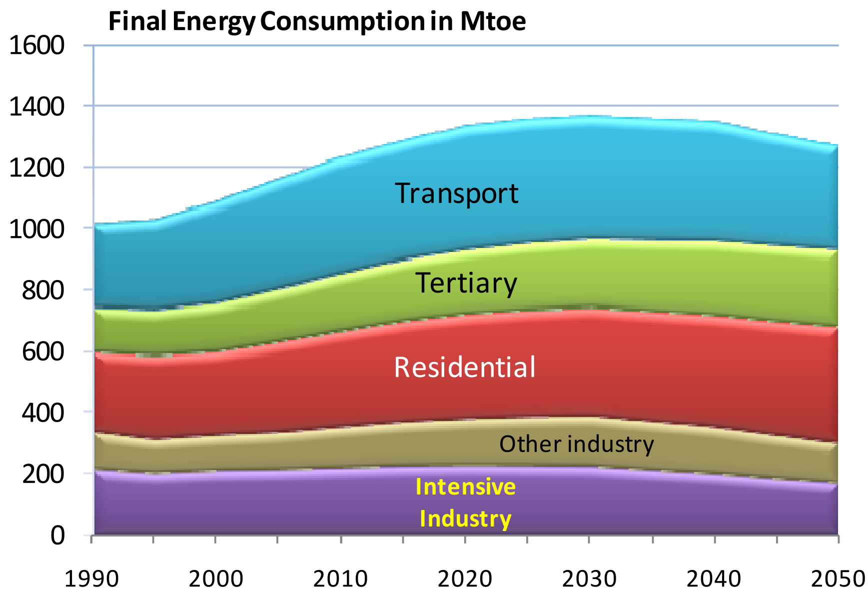
The dependence on oil imports is less aggravated because the EU-25 is already in 2005 highly depending on oil imports. The incremental needs for oil imports by 2030 represent 16% of oil imported in 2005 and they are required mainly to replace the lacking indigenous production.

The indigenous production of solid fuels also declines continuously over the entire projection period. This trend is the result of imported coal gaining competitiveness vis-à-vis indigenous solid fuels the extraction of which in the EU-25 involves upward slopping marginal costs. Indigenous production of solid fuels by 2030 is projected to reduce at a level which is 60% of the volume produced in 2005. Since the use of solid fuels in power generation re-emerges beyond 2020, net imports of coal increase (by 3% per year in the long term). Net imports of coal by 2030 are projected to double relative to their 2005 levels. The analysis does not associate risk of high prices or disruption with these incremental needs for coal imports.

4.3. Final Energy Demand

The structure of final energy consumption by sector of activity reflects macroeconomic trends. The share of energy intensive industry in total final energy consumption declines throughout the projection period, going from 18% in 2005 down to 13% in 2050. Energy consumed in buildings (offices, houses, etc.) represents the fastest growing use of energy: 1% average growth rate per year until 2030 and then growth by 0.4% per year in the period 2030 to 2050. The share of this sector in final energy consumption rises from 40% in 2005 to 50% in 2050. Energy demand for transport considerably grows in the short and medium term but it slows down in the long term and even declines beyond 2030, as a result of high oil prices and saturation effects. Energy used in transport represents a constant share of about 30% throughout the projection period.

Figure 6: Baseline Scenario EU25 - Final Demand by Sector

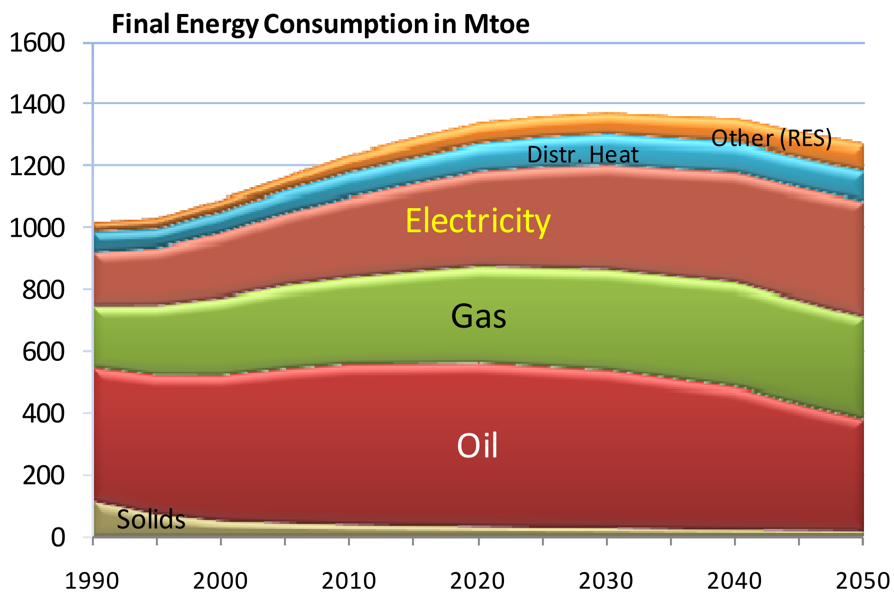


Energy demand in industry is projected to grow at moderate rates due to considerable energy intensity gains related to the structural changes towards less energy intensive manufacturing processes. The projected rather high rates of increase in the energy demand of the tertiary sector are in line with a gradual shifting of the European Economy towards services. The increase of final energy demand by households is projected to slow down as a result of saturation effects, except for electricity demand which is expected to grow driven by new specific uses of electricity. The predominant role of transport sector in final energy demand growth is remarkable. Transport remains the fastest growing energy demand sector. However in the long term, growth is slowing down as a result of saturation effects, high oil prices and technology progress. The continued growth of the transport sector explains the persistence of high demand for petroleum products throughout the projection period.

Final demand for polluting fuels, such as solids and residual fuel oil, is declining. Conversely, the demand for lighter oil products, mainly diesel oil and gasoline, shows stability as a result of their massive use primarily for transport and secondarily for chemicals.

Final demand for natural gas increases throughout the projection period albeit at rates that are slowing down over time. Compared with total gas consumption in 2005, the additional needs for gas to cover final gas consuming uses represent half of total additional gas requirements.

Figure 7: Baseline Scenario EU25 - Final Demand by Fuel



Electrification manifested by an expanding use of electricity in all sectors is projected to continue in the Baseline scenario, as also exhibited in past trends. In the Baseline scenario, electricity demand grows at an average annual rate of 1.48% in the period 2005-2030 and reaches a market share of 25% in 2030 steadily growing from a share of 17% in 1990. Electrification reflects the fact that electricity drives technological progress, comfort and competitiveness of the new economic growth of Europe. It is therefore justified to consider sustainability and economic efficiency in the power sector as playing a key role in the European energy strategy. The numerous processes, appliances and applications that can use energy only in the form of electricity, but also the special features of electricity, such as easy controllability, cleanliness at the point of use, etc., explain the increasing use of electricity in the EU-25 energy system.

Even though demand for electricity grows faster than total energy, the rate of growth slows down in the long term, mainly as a result of saturation effects. Beyond 2030 the demand for electricity continues to display positive but lower growth rates (0.52% per year on average in the period 2030-2050). For the Baseline scenario, as a consequence of the underlying assumptions about technology development, electricity is not projected to penetrate in the transport sector, except for specific uses such as train transport.

The use of renewable energy in thermal uses of final energy demand sectors advances over time, particularly in the long term driven by the increasing use of bio-fuels in automotive transportation. For the Baseline scenario it is projected that bio-fuels penetrate up to 10% in total use of oil products in cars.

Distributed heat and steam plays a rather minor role in the Baseline scenario. Nevertheless, despite niche market applications driving its further development, distributed heat and steam is not assumed to massively take place in the longer term, leading to low shares (below 7%) of this type of energy distribution in total final energy consumption, in the period beyond 2030.

In summary, the final energy outlook for the Baseline scenario shows a split of final energy uses in two main sub-sectors, namely transportation where oil products have a dominant role and buildings driving growth of demand for electricity and gas. Oil is confined into a single sector and bio-fuels or other new automotive energy forms hardly succeed to penetrate in the long term. Energy needs for industrial processing display an increasingly small share in total final energy.

4.4. Power Generation

As already mentioned, demand for electricity grows substantially throughout the projection period and its trajectory diverges from the pace of total energy requirements.

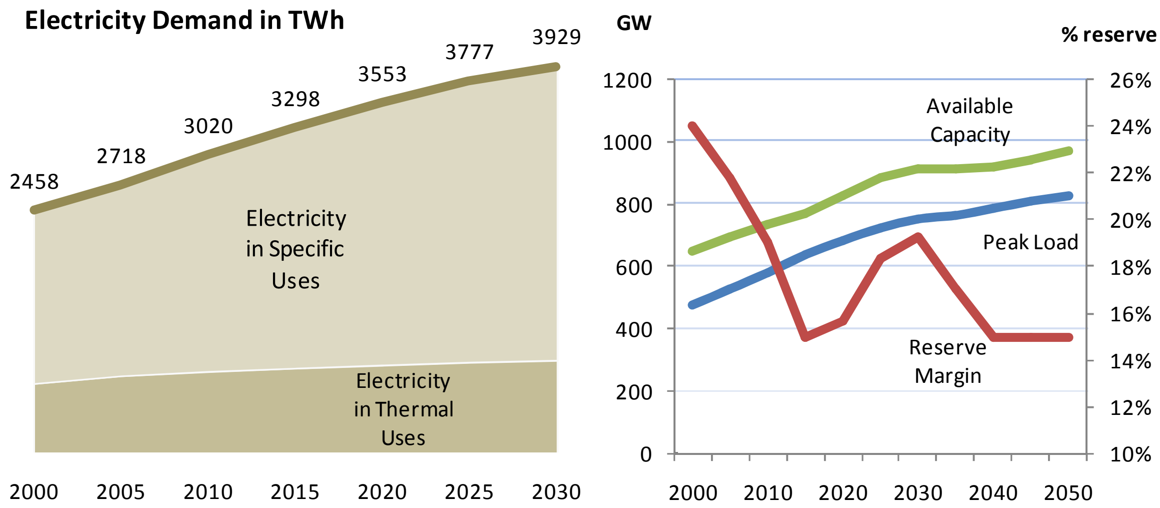
Electricity demand is closely linked with GDP growth: the income elasticity of electricity is lower than one but remains at a high level (0.75 on average). The rate of growth of demand for electricity in the residential and tertiary sectors is in a range between 1.5 and 2% per year, whereas in industry it is below 1% per year in the long term. Electricity demand is driven by the expansion of specific electricity uses. The projected changes in demand pattern induce a slight reduction in the average load factor of electricity consumption which stabilizes at a level just below the level of 60% in the long term.

For different reasons electricity supply capacity in the EU25 is largely sufficient to cover peak load: the reserve margin after corrections for availability of dispatchable power is estimated at 24% in 2005. In the Baseline scenario, power capacity expansion is optimized and so in the long term the reserve margin is gradually reduced to 19% in 2030 and 15% in 2050. Intermittent renewables are not accounted for in the estimation of available dispatchable power.

Installed power capacity is projected to increase by 50% to 2030 compared to today and by 70% to 2050.

Considerable investment in power generation takes place in the Baseline scenario: in the period 2005-2030 822 GW[5] of new power stations have to be constructed in order to cover growing electricity demand and replace old plants that are decommissioned (439 GW). For the period 2030-2050 new investment is estimated at 605 GW and decommissioning at 470 GW.

Figure 8: Baseline Scenario EU-25 – Electricity Demand and Reserve Margin



The larger part of investment in power generation is likely to take place during the period 2010 to 2030 (681 GW or 34 GW per year on average). This implies that considerable restructuring of power generation fleet is likely to take place in the future; therefore technology choice is extremely important to ensure long term sustainability of the power sector.

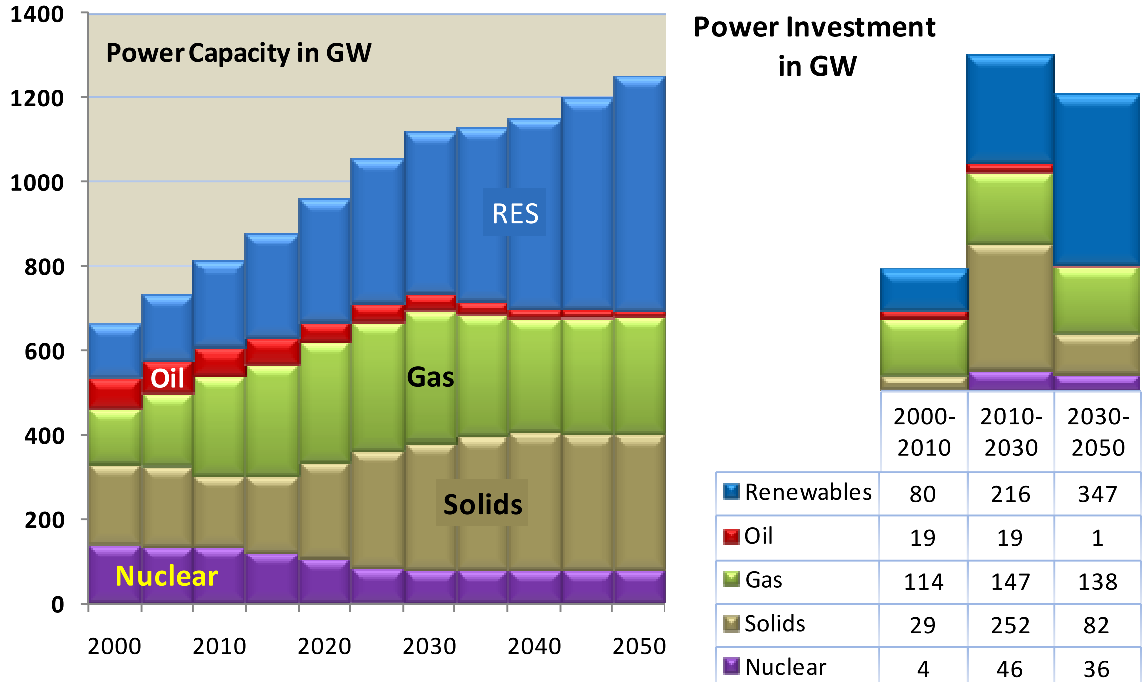
For the Baseline scenario, the choice of investment is assumed to take place on strict economic grounds: meet demand at long term least cost by respecting reliability constraints. Market failures or adverse effects which relate to sustainability issues are not taken into account in this scenario.

In the short term power generation investment is dominated by combined cycle gas as a result of construction commitments taken in the past. New GTCC plants represent almost 50% of total power investment in the period 2005 to 2010, despite high gas prices.

[5] It is reminded that intermittent renewables, such as wind and solar, account for equally to thermal plants in terms of installed capacity but deliver electricity at capacity factors that are far lower than thermal plants.

Gas power investment has low capital cost, high efficiency and low emissions; therefore it is an attractive option for investment in uncertain conditions as those currently experienced. In addition, gas power plants are attractive for covering the medium and peak load, which grows in importance as the electricity load curve gradually transforms driven by changes in electricity consumption patterns. Also, CHP applications, which are found to develop considerably in the Baseline scenario, drive higher use of gas-based electricity. For these reasons investment in gas power retains a significant share throughout the projection period. However, its share in total power investment drops beyond the short term to 30% in 2015 and furthermore to 20% on average in the long term.

Figure 9: Baseline Scenario EU-25 – Power Generation Capacity and Investment



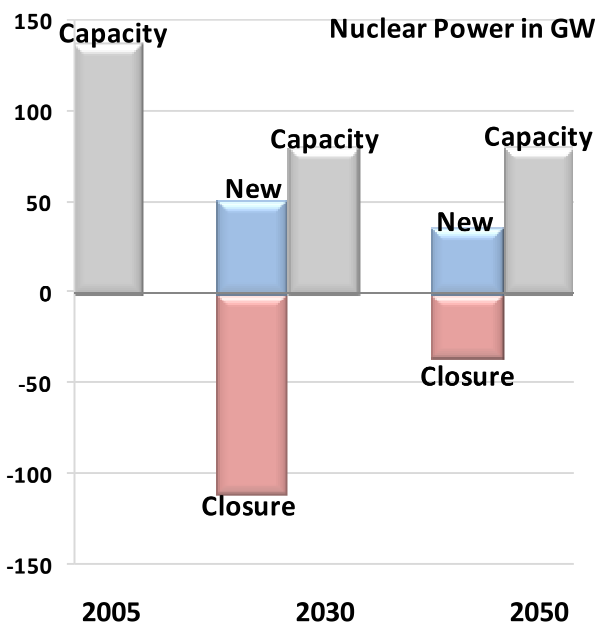
	2000-2010	2010-2030	2030-2050
Renewables	80	216	347
Oil	19	19	1
Gas	114	147	138
Solids	29	252	82
Nuclear	4	46	36

In the longer term, the continued deterioration of gas competitiveness in power generation vis-à-vis coal induces a reversal of the short-term trends. Gas power investment slows-down considerably and investment in coal plants re-emerges. Investments in coal and lignite fired plants, which figured with a share of only 11% of total power investment in the short term, become the dominant choice for power expansion in the period beyond 2015 and mainly beyond 2020. The Baseline scenario projects commissioning of more than 250 GW of new coal plants in a period of 20 years that is between 2015 and 2035. Compared to total installed capacity of 190 GW of coal and lignite plants in 2005, the volume of new investment in coal power should be qualified as a challenge for the industry, if new cleaner coal technology is targeted. No CCS power plants are projected for the Baseline scenario, since carbon emissions are not restrictive. Nevertheless, new investment in coal power is projected to rely mainly on advanced technologies, such as supercritical coal plants.

Coal-based power is also favoured by the diminishing contribution of nuclear in base load since nuclear energy gradually decreases as a result of nuclear policy assumed for the Baseline scenario. The use of coal in power generation increases considerably after 2015 and particularly more after 2020. As a consequence, despite the lower emission factor per unit of output of new supercritical coal plants, carbon dioxide emissions from power generation rise significantly after 2020.

Coal-based power, which represented 29% of total power generation in 2005, does not grow in the short term reaching a share of 27% in 2015; in the longer term the share of coal generation increases attaining 40% in total generation by 2030 and in the longer term. Since total power generation also increases, the volume of coal based generation by 2035 doubles relative to 2005.

Figure 10: Baseline Scenario EU25 - Nuclear Energy



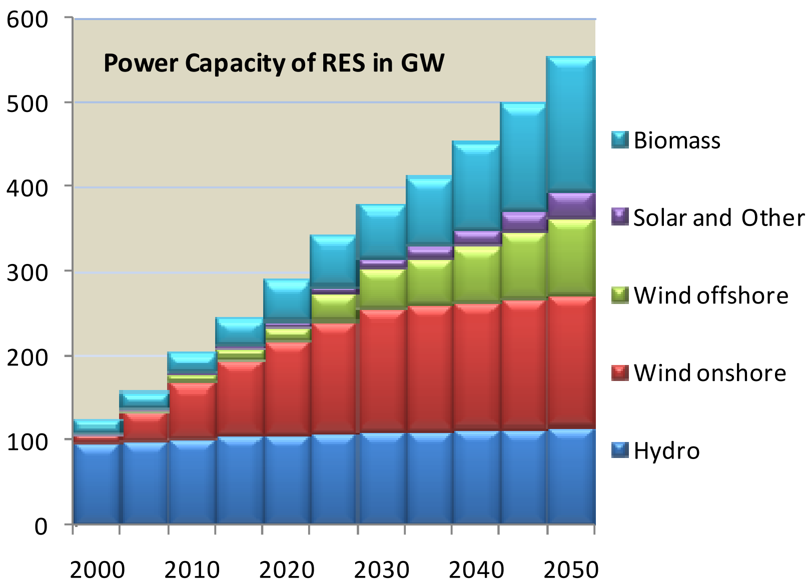
The development of the nuclear electricity sector, under the conditions assumed for the Baseline scenario, reflects EU-requirements to close a number of plants in new member states, the decommissioning of old plants at the end of their conventional life time, the nuclear phase out in three EU countries and the likely decisions in large nuclear countries not to replace the entire nuclear park after decommissioning.

This explains the decline of nuclear capacity leading by 2030 to a level which is 40% lower than 2005.

New nuclear investment of 50.6 GW until 2030 as projected in the Baseline scenario is less than decommissioning and phasing-out (110.9 GW until 2030). Beyond 2030, nuclear capacity is projected to remain stable at the level reached by 2030; therefore new nuclear investments of 36 GW in the period 2030-2050 are just replacing decommissioned plants of equal volume.

Petroleum products have a very small share in power generation and their role is limited in certain specific applications, like in isolated islands or areas.

Figure 11: Baseline Scenario EU25 - Capacity of Renewables in GW



Renewables used for power generation show a remarkable development. Supportive policies are assumed to apply in the short-medium term and gradually vanish in the long term. Renewables' technology benefits from learning by doing and economies of scale, so they are increasingly adopted as technological improvement counterbalances the gradually decreasing subsidies.

Wind power, in particular, displays economic competitiveness over time. As a consequence, on shore wind develops rapidly in the short and medium term: 140 GW of new onshore wind mills are constructed between 2005 and 2030. In the long term, investment in on shore wind mainly serves to replace decommissioned wind farms (110 GW in the period 2025 to 2050) as further development of new sites is less attractive.

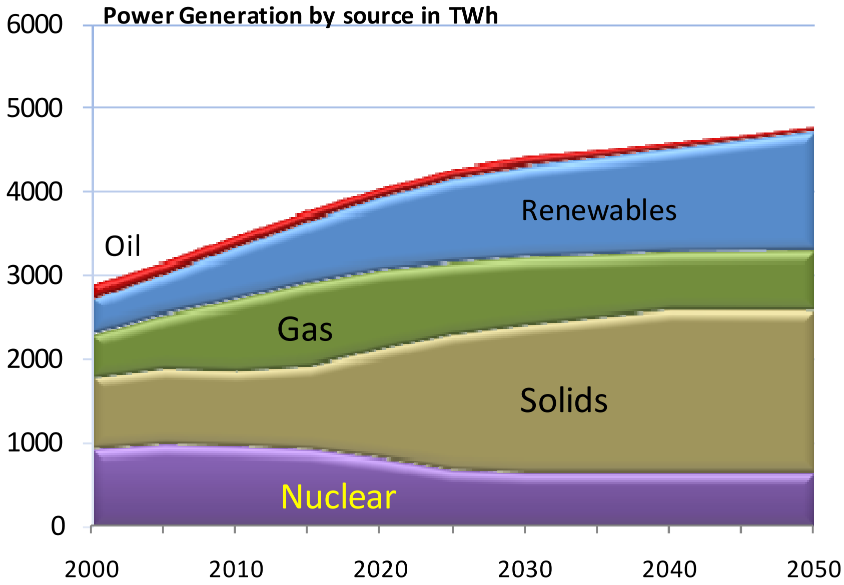
Off shore wind starts from a low level and develops slowly in the medium term as progress related with scale and connectivity is low. Off shore wind is projected to develop much faster in the longer term and gain economic competitiveness in power generation: 110 GW are built between 2015 and 2050 (48 GW until 2030).

Wind power by 2030 attains 192 GW, five times up from 2005 and 247 GW in 2050. By 2030, although wind power represents 18% of total installed capacity it produces only 10% of total electricity. Nevertheless, this share is high with respect to current technical possibilities; therefore additional investment in power grid reinforcement will be required.

The development of solar energy, mainly photovoltaic technology, is far slower. Over the entire period, 45 GW of PV are built of which 35 GW beyond 2030. Solar energy represents a mere 0.2% by 2030 and 0.4% in 2050. Other RES such as tidal energy, small hydro and geothermal energy for power generation play a minor role and develop in some countries where specific potential exists. The contribution of large hydroelectric energy is projected to be rather stable throughout the time horizon.

Biomass based power generation shows significant development in Baseline scenario. This development includes power from waste energy which is an attractive option in certain specific cases but is limited in volume, as well as co-firing of solid fuels with biomass in conventional power plants. The Baseline scenario foresees 58 GW of new biomass-specific power plants until 2030 and 110 GW beyond 2030. Most biomass plants are CHP plants and use a variety of new technologies, such as high temperature combustion, integrated gasification combined cycle and bio-gas turbines or ICE. The share of power generation from biomass in total power generation increases from 2.5% today to 5% in 2030 and 10% in 2050.

Figure 12: Baseline Scenario EU25 – Power Generation by Source

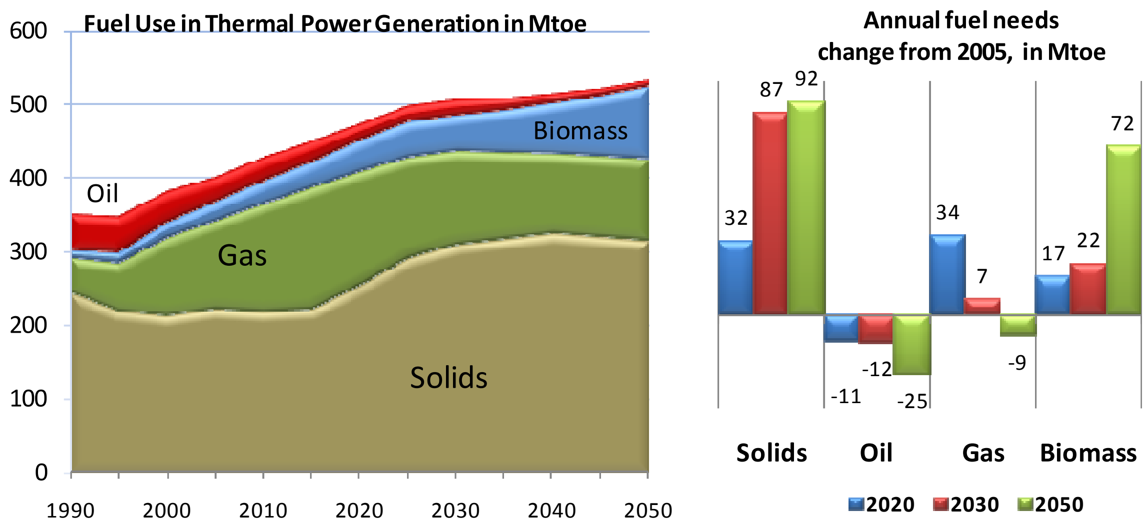


As already mentioned the share of nuclear energy decreases substantially, in the Baseline scenario. The share of gas-based power peaks in 2015 reaches 27% in total power generation, up from 20% today, but decreases in the long term down to 18% in 2030 and 15% in 2050. Power from coal and lignite gets a constant share below 30% until 2020 which then increases to 40% until the end of the time horizon. Coal-based power becomes gradually the main source of base load generation. It is remarkable that despite the business-as-usual character of the Baseline scenario, renewables-based electricity (including large hydro) develops fast and becomes in 2030 as large as total coal generation and also 50% larger than nuclear electricity. Renewables-based electricity represented only half of nuclear electricity in 2005. Renewables attain in 2030 a share of 25% in total power generation up from 16% in 2005. This share reaches 30% in 2050. Without including large hydro, RES-power from 5% in total power generation in 2005 rises to 16% by 2030 and 21% by 2050.

Thermal efficiency of fossil fuel power plants progresses considerably as a result of investment in gas combined cycle and advanced supercritical coal plants. Average thermal efficiency from 36.1% in 2000 and 37.9% in 2005 it rises to 48.8% in 2030 and approaches 50% by 2050. The share of electricity from cogeneration plants also rises: from 16.7% in 2005 up to 28.3% in 2030, which implies that CHP electricity doubles in volume from 2005 to 2030.

These efficiency improvements imply that fossil fuel consumption for power and steam generation grows at rates lower than for electricity and steam generation: average productivity of thermal generation grows by 0.5% per year.

Figure 13: Baseline Scenario EU25 - Fuels used by Thermal Power Generation



The outlook of fuel use for thermal power generation shows that natural gas plays an important role in the medium term (2020). Compared to 2005, 30% additional volume of gas is likely to be required by the sector in 2020 and 38% in 2015. Gas consumption by the sector is likely to decrease in the longer term and stay at a level comparable to today consumption. This result implies that the power sector will need additional gas supply contracts for a rather short period of time.

The profile of demand for gas by the power sector implies that the gas supply sector will face difficulties to offer attractive long term contracts. This difficulty comes also from the restructuring with respect to gas supply origins that the gas supply sector will undergo given the declining prospects for indigenous gas production. Therefore, concerns are raised concerning affordability and security of supply of gas, particularly in the medium term when peak of gas demand is also likely to occur.

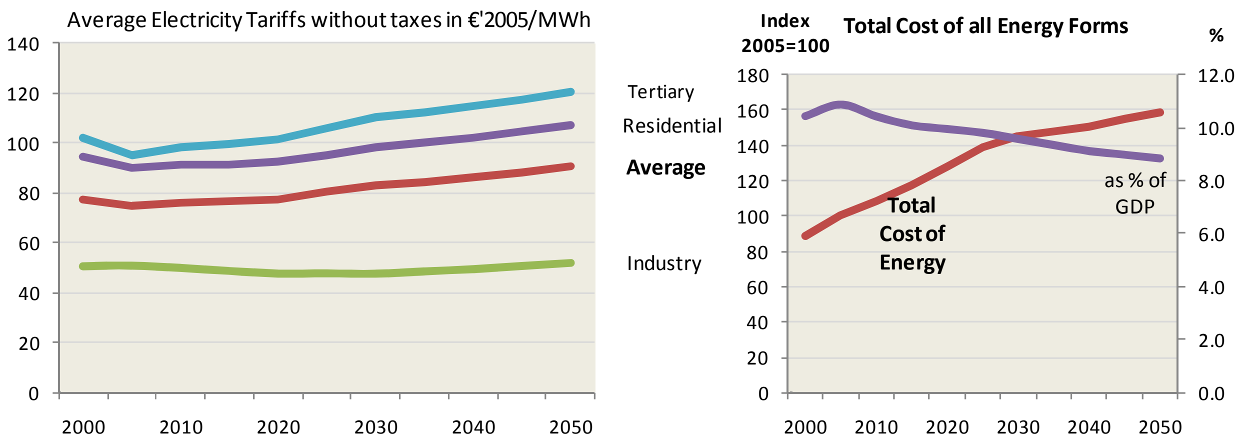
As mentioned, coal re-emerges in the long term. Beyond 2025, the sector is likely to require 40% higher volume of coal and lignite than in 2005. It is expected that the incremental demand will be covered by imported coal. This implies that in some areas of Europe coal-related infrastructure has to expand.

Demand for oil by the power sector declines throughout the projection period. Biomass-based energy forms will be increasingly used for power and steam generation: by 2050 the volume of biomass in Mtoe will be at a similar level as total gas volume.

4.5. Costs and Prices of Energy

Because of rising world fossil fuel prices and despite technological progress and competition, consumer energy prices in Europe are projected in the Baseline to increase by 0.85% per year on average in real terms in the period 2005-2030 and by 0.5% per year in the period 2030-2050. Despite these increases total cost of energy as a percentage of GDP declines over time, from 10.86% in 2005 to 9.57% in 2030.

Figure 14: Cost of Energy and Electricity Tariffs



Total cost of investment in power generation, in cumulative terms starting from 2000 until 2030, approaches 950 billion €'2005 and in total 1900 billion until 2050. Annual investment expenditure in real terms increases over time by 2.5% per year on average. Particularly for the long term, the unit cost of power investment increases as a result of opting for coal and renewables which have high capital costs. As the structure of power generation changes in the long term in favour of coal and renewables, the part of generation costs that represent fixed (capital and O&M) costs increase over time. Conversely variable costs decrease slightly in the long term.

Electricity tariffs are found increasing in Baseline scenario but at slower pace than fossil fuel prices. Average tariffs grow by 0.4% per year in real terms, but tariffs by sector follow diverse trajectories. Industrial tariffs are projected to remain stable over time, whereas tariffs for use of electricity in buildings increase faster than average. This trend reflects changes in the cost structure of power generation and diversity of marginal costs for mid- and base load. Mid-load's share in total electricity demand increases over time and its coverage involves increasing fuel costs, whereas base load involves stable fuel costs over time. As market competition evolves in this sector and the internal EU market is established over time, the model projects that cross-subsidies between customers gradually vanish and similarly tariff diversity across countries also decline.

Bilateral trade of electricity is also projected to change leading to a more balanced distribution of power exports among countries, a trend which is also facilitated by increasing investment in base-load generation, based on nuclear and coal, by several new EU-member-states. Consequently, electricity tariffs tend to become more uniform across European countries, involving higher increase of tariffs in countries with low prices today.

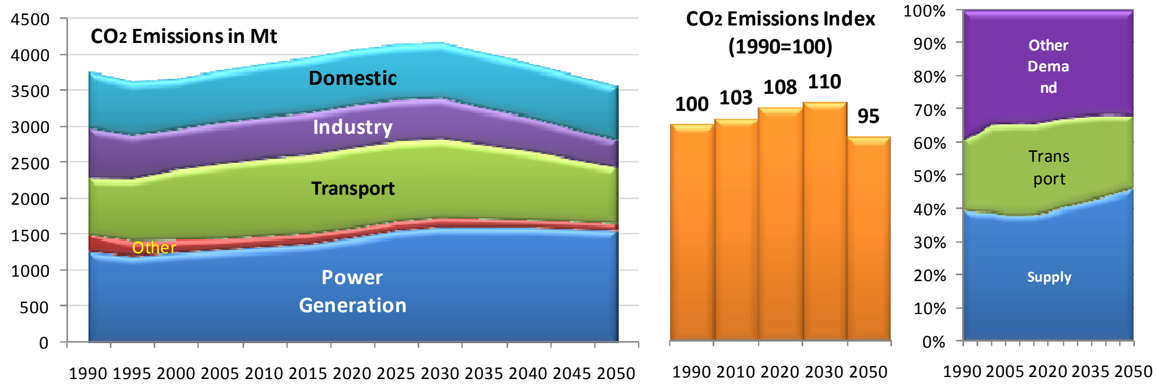
All sectors are affected by the increasing cost of energy. Households and services sectors face higher increases in the cost of energy than industrial and transport sectors. Industry is less affected by increasing energy prices, mainly because this sector undergoes restructuring shifting away from energy intensiveness. Households and tertiary (the domestic sector) are likely to face considerable increases of their energy bill, because of increasing prices and their increasing energy and electricity needs. The tertiary sector partly compensates increasing energy costs by energy productivity gains. The increasing spending for energy used by households is also attributed to the increasing purchase of appliances and devices which use electricity. The cost of transportation also increases over time. In this sector capital expenditures grow faster than fuel expenditures, a trend that is related to growing efficiency of engines and transport means. End-user bills for transportation are less affected by high fuel prices because fuel costs represent a rather small fraction of total transportation cost given that the sector bears high capital cost and high taxation.

4.6. Carbon Dioxide Emissions

The Baseline scenario shows that business-as-usual trends imply increasing carbon dioxide emissions. The gap between business-as-usual emissions and the emissions permitted by Kyoto and post-Kyoto policies is found to be continuously widening. The gap is almost 10% of total energy-related emissions in 2010 and rises to 40% in 2030 (for a target of -30% from 1990) and 45% in 2050 (for a target of -50% from 1990). The

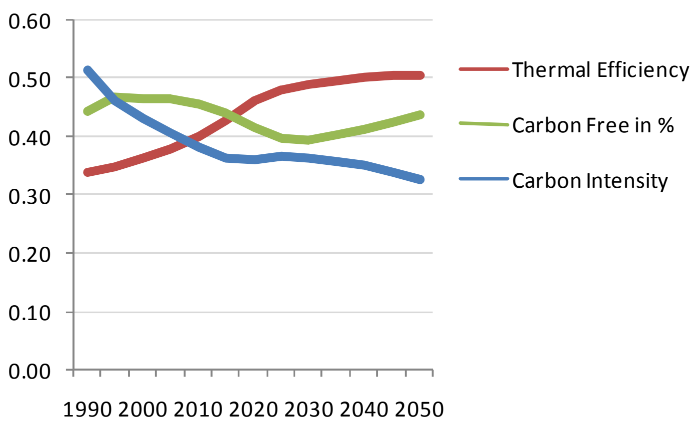
Baseline scenario clearly fails with respect to climate change mitigation aspirations.

Figure 15: Baseline Scenario EU25 – CO2 Emissions



The emissions could be considerably higher if the Baseline scenario did not involve significant decrease of energy intensity of the economy. Energy efficiency, resulting from structural changes in the economy, technological progress and saturation, is almost the exclusive reason for obtaining stabilisation or low growth of carbon intensity of GDP in the Baseline scenario.

Figure 16: Baseline Scenario - EU25 - Carbon Indicators for Power Generation



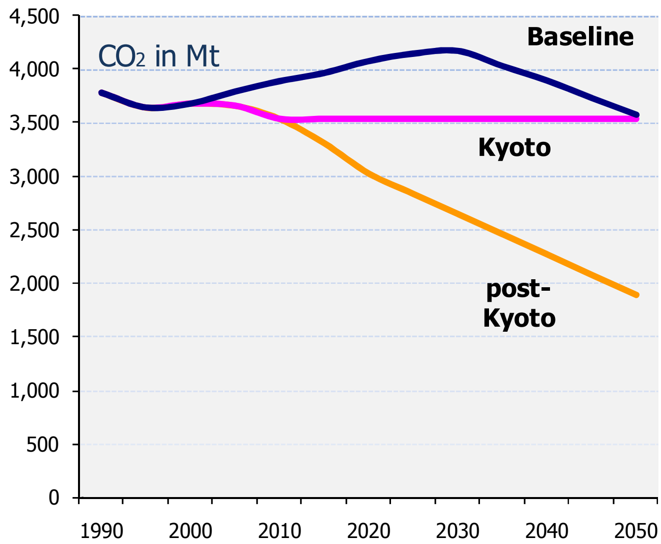
The carbon intensity of electricity generation drops throughout the projection period at an average rate of 0.76% per year. Average emissions from 0.51 tCO2 per MWh in 1990 decline to 0.36 in 2030 and to 0.32 in 2050. However, this reduction takes place mainly in the short and medium term, as already in 2020 every MWh produced involves 30% less emissions of CO2 than it was in 1990. This is mainly the outcome of using more gas in power generation. Beyond 2020, the carbon intensity of power generation almost stops to improve, despite the rapid growth of renewables used in power generation. This long term trend is a result of using more coal in power generation and the decline of nuclear energy. The changing structure of power generation in the long term implies that the share of the power sector in total energy-related CO2 emissions increases beyond 2020 and reaches 45% in 2050.

The improvement in the carbon intensity of the power generation is due to changes in the mix of fossil fuels in the medium term, the improvement of thermal efficiency and the high growth of renewables in the long term. The remarkable growth of renewable energy in power generation does not counterbalance the decline of nuclear energy as regards CO2 emissions. Carbon-free power, albeit its increase in volume (18% higher in 2030 and 40% in 2050 from 2005), keeps a non increasing share in total power generation. Carbon free power as percentage of power generation drops in the period from 2010 to 2030 as a result of the decline in nuclear energy and increases again after 2030 reflecting the increasing use of renewables.

4.7. Non sustainability of the Baseline Scenario

In summary, the Baseline scenario represents an energy future for Europe which is efficient with respect to cost of energy but is unsustainable with respect to carbon emissions and security of supply.

Figure 17: Baseline Scenario - EU25 – CO2 Emissions versus targets



According to the Baseline, carbon emissions deviate from targets, both with respect to the Kyoto protocol commitments and to the post-Kyoto.

Also, according to Baseline projections, energy import dependence of Europe is likely to increase dramatically. Concerns particularly refer to exposure to risk regarding gas procurement conditions and the adverse effects on Europe's power generation sector.

Alternative Scenarios

Update February 2007

5. Definition of Alternative Scenarios

The analysis of the Baseline scenario identifies the need for additional policies and measures, especially with respect to the implications of energy import dependence and on climate change. For this purpose, alternative scenarios are quantified.

Analysis of Baseline results clearly demonstrated that CO_2 reduction policies are very closely linked to the two other drivers, import dependency and economic competitiveness. With this in mind, we decided to impose on all alternative scenarios, which are quantified with the models, exactly the same ambitious target for mitigating carbon dioxide emissions: under all alternative scenarios the EU-25 is constrained to meet an overall CO_2 emissions cap of -30% in 2030 and -20% in 2020, compared to 1990. For longer-term analysis, this cap is assumed to become more restrictive: -40% in 2040 and -50% in 2050. This makes the alternative scenarios comparable with each other.

However, the alternative scenarios, as well as a series of other sensitivity analysis scenarios that have also been carried out, adopt different assumptions in terms of the energy policy approach and the technological developments that are needed to meet the emissions cap. In these terms, the alternative scenarios are defined as follows:

- The ***Efficiency & RES*** scenario assumes that policy focusses on the fields of energy efficiency and renewables. For this purpose, the scenario involves a package of measures promoting energy savings and highly efficient appliances, plus policies facilitating further deployment of renewables, including support for biomass through the Common Agricultural Policy. This scenario does not involve any revision of nuclear policy as compared with baseline and excludes the development of carbon capture and storage (CCS) technology.

- The ***Supply*** scenario assumes that policy focusses mainly on power generation in order to obtain a low carbon energy system and meet the emissions cap. The scenario does not foresee any additional efforts to promote energy efficiency or renewables over and above the Baseline scenario. This scenario assumes that a new nuclear policy is adopted and put in place, and that CCS is facilitated and successfully developed. The new nuclear policy involves the possibility of extending the lifetime of old nuclear plants (selectively depending on technical constraints), cancellation of planned nuclear phase-out in three member states (but no development of nuclear in ten member states that have had no nuclear energy in the past) and the success of new nuclear fission technology. Regarding CCS, the scenario assumes that CCS-enabled coal- and gas-fired power plants become commercially available and that CO_2 transport and storage develops throughout Europe.

- The ***Role of Electricity*** scenario does not exclude any means or options towards a low carbon energy system in Europe. This scenario involves policies promoting energy efficiency on the demand side and policies supportive to renewables as envisaged in the Baseline scenario, but without incorporating any additional policies for renewables or biomass. In addition, this scenario assumes that new demand-side electro-technologies will successfully develop. Some of these technologies improve energy efficiency in specific electrical uses, such as efficient lighting and motor drives, while others facilitate higher penetration of electricity in substitutable energy uses, including heat pumps and plug-in hybrid vehicles. On the supply side, the *Role of Electricity* scenario mobilises, alongside renewables, both the new nuclear policy and CCS technology, as specified for the *Supply* scenario.

All alternative scenarios assume that the emissions cap is applied to the EU as a whole and that it will be possible that all sectors and countries of the EU contribute under a perfect allocation scheme to emissions reduction. In other words, all sectors and countries contribute as much as needed to obtain the overall emissions reduction under the condition that all sectors face exactly the same marginal abatement cost. This marginal cost, called “carbon value”, corresponds to the marginal value of the overall emissions cap. The carbon value is a measure of the relative difficulty of meeting the constraint and does not entail any direct cost to consumers or producers, who only bear indirect costs as a result of energy system restructuring.

All alternative scenarios follow the post-Kyoto emissions path (see Figure 8) and involve considerable energy restructuring. Each scenario however enables a different kind of restructuring in order to lead to a low carbon energy system. Through an optimal market equilibrium approach, the model determines the best mix of means and options to reach the constrained emissions path.

The publication on January 10, 2007 of the European Commission’s proposal on long-term energy policy, the Strategic Energy Review, manifests Europe's willingness to place a seriously long-term binding constraint on carbon dioxide emissions. The Commission is proposing a series of new policies and targets in the domains of energy efficiency, renewables, nuclear policy, carbon capture and storage in power generation and new technologies in both demand and supply. Although the emissions reductions set out in the scenarios were defined long before publication of the Commission's paper and therefore do not correspond exactly to the targets it proposes, they are nevertheless based on very substantial and increasing reductions in emission levels.

6. The Supply Scenario

6.1. Introduction

As mentioned the *Supply Scenario* puts emphasis on the restructuring of energy conversion systems, essentially of the power generation sector, in order to meet the requested restriction on carbon dioxide emitted by the whole energy system of EU25. Measures applying in demand sectors and the promotion of new electro-technologies are not envisaged for this scenario. Supportive policies to renewables are assumed unchanged from Baseline.

For power generation the options for reducing carbon intensity beyond its level in Baseline include nuclear energy, carbon capture and storage (CCS), renewables and changes in fossil fuel mix towards using more gas. Nuclear and CCS need several years to develop, whereas more use of gas and renewables can develop over shorter time periods. The restrictions on nuclear energy are removed in the *Supply Scenario*, except for the countries that have never used nuclear in the past.

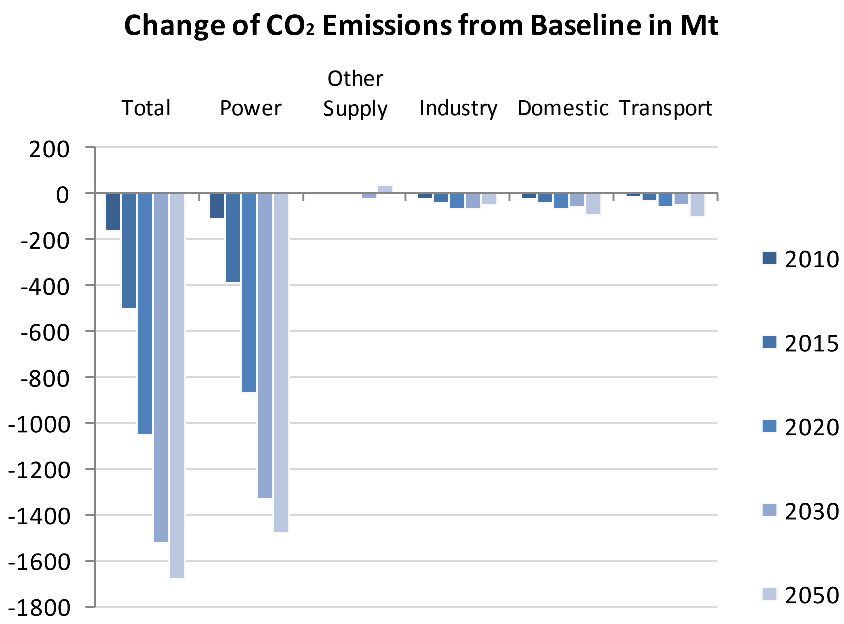
The main driver of changes within the Supply Scenario is that marginal costs of reducing CO2 emissions are lower for power generation than for final demand sectors. The potential for carbon emission reduction is also considerably higher for the power sector. Therefore optimality, in accordance with least-cost allocation of carbon abatement effort among the sectors, suggests that the power sector has to deliver by far the largest emission reduction.

6.2. Emission Reduction by Sector

The power sector reduces emissions by 85-95% from Baseline in the period 2030-2050, whereas the reduction by final demand sectors, including transport, does not exceed 12% from Baseline.

Transport reacts very slowly over time and less than other final demand sectors, except in the period close to 2050 when it undergoes significant change with bio-fuels and fuel cells getting notable shares within road transportation: 21.7% for bio-fuels and 13% for fuel cells. Energy consumption for transportation reduces in a range between 2 and 2.8% from baseline over the period 2020-2040. This decrease accentuates in the longer term and attains 12.5% in 2050.

Figure 18: Supply Scenario - CO2 Emission Reduction



All other energy demand sectors reduce their total energy consumption in a range between 4 and 5% from baseline, over the entire time period. Energy intensive industry undertakes higher reduction effort (-6%) than the non energy intensive industry (-2%).

Energy efficiency in end-uses improves from baseline in a range between 3.5% for 2020 and 5% for 2030. This improvement is far below potential of energy efficiency.

6.3. Power Sector

The power generation sector undergoes considerable restructuring in the Supply Scenario and becomes an energy transformation sector with very low carbon intensity. CO2 emissions per MWh generated, from 0.41 in 2005 drops to 0.15 in 2020, 0.09 in 2030 and as low as 0.02 in 2050. From 2020 to 2030, 60% of generation is based on nuclear and renewables, which is 18 percentage points up from Baseline. Towards 2050, nuclear and renewables represent 74% of total generation, which is 30 percentage points up from Baseline.

Figure 19: Supply Scenario EU25 - Structure of Power Generation

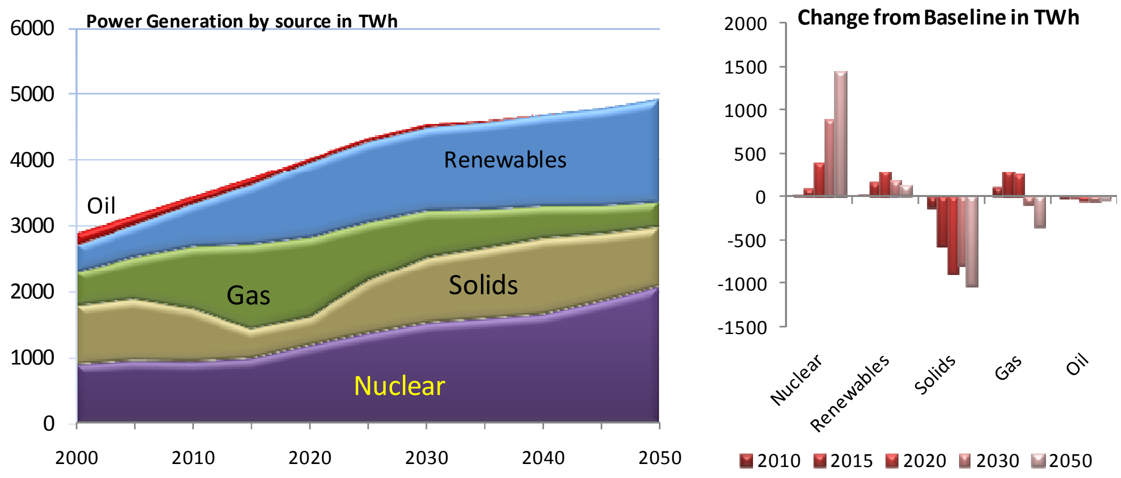
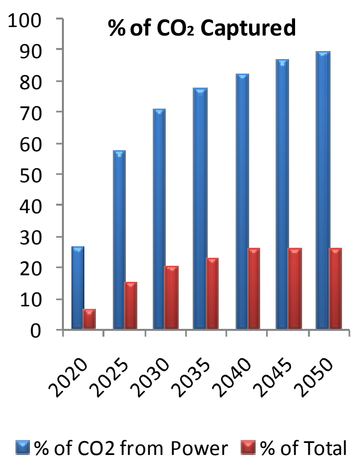


Figure 20: Supply Scenario EU25 - Contribution of CCS



From 2020 onwards, new power plants burning fossil fuels are increasingly equipped with CCS technology. In 2020, 27% of CO2 emitted from power plants is captured. This increases in 2030 up to 71% and in 2050 up to 90%. All coal plants built in the period from 2020 to 2030 and 22% of gas-fired plants are equipped with CCS. Coal-based CCS technology dominates also in the period beyond 2030. CCS peaks in 2040 but by 2050 its share reduces down to its level in 2030, because bigger development of nuclear and renewables takes place during the last decade of the projection. By 2050, CO2 captured represents 40% of total CO2 emissions avoided by Supply Scenario when compared to Baseline emissions. Capture of CO2 stabilises in the long term at about 26% of total emissions. The storage of CO2 uses cumulatively over time a rather small share (about 20%) of what is known today as the total potential of underground storage of CO2.

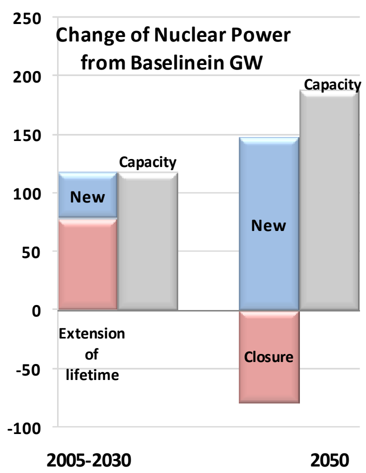
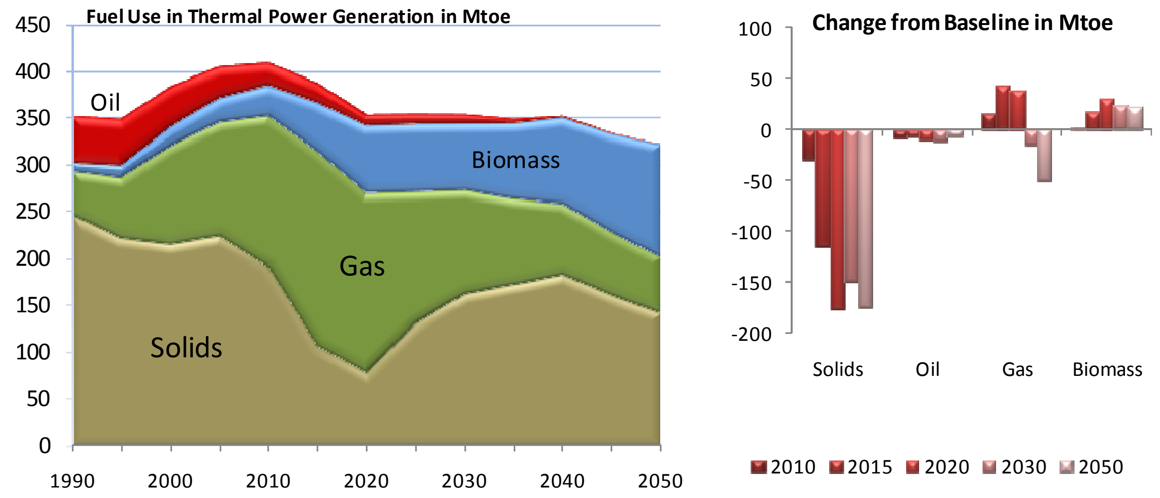


Figure 21: Supply Scenario EU25 - Nuclear "Renaissance"

The nuclear industry development under the Supply Scenario can be characterized as "nuclear renaissance". Nuclear capacity from 137 GW in 2005 becomes 199 GW in 2030 (45% rise) and 269 GW in 2050 (96% rise). It is estimated that 78 GW of nuclear undergoes extension of life time. In addition, 91 GW of new nuclear plants are built during the period 2005 to 2030; that is 40 GW more than in Baseline. New constructions in the period 2030 to 2050 amount to

184 GW and are mainly applying advanced nuclear technologies. Supply and treatment of nuclear fuel and waste are taken into account as far as their energy consumption is concerned but not with respect to their potential which may become a factor restricting high development of nuclear. It is assumed that advanced nuclear technologies that develop beyond 2030 are more efficient than the current nuclear technology with respect to requirements for nuclear fuel treatment and waste.

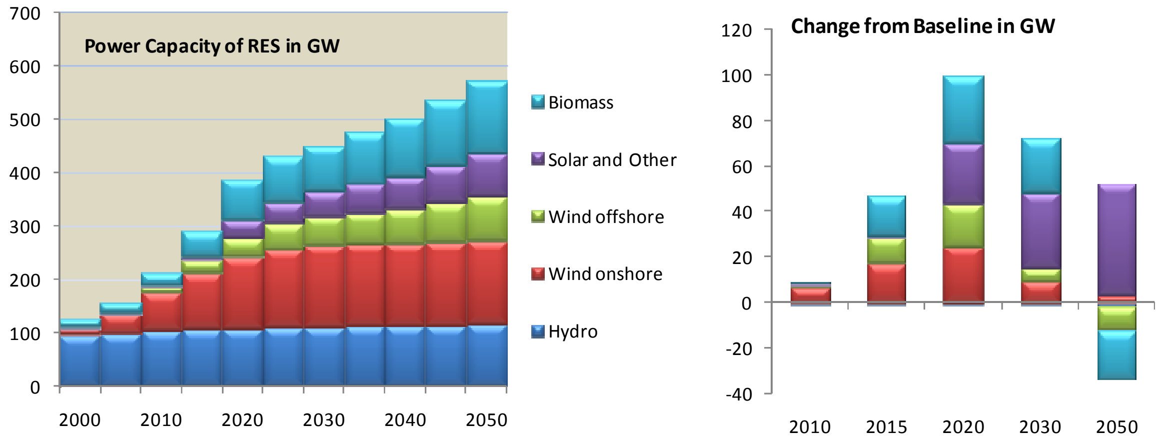
Figure 22: Supply Scenario EU25 - Fuels used by Power Generation



The new structure of power generation involves significantly lower demand for fossil fuels than in Baseline. Total thermal power generation, after peaking in 2010, shows continuous decline. In the short and medium term, and in particular before the introduction of CCS in 2020-25, gas-fired generation seems to be the cheapest way of reducing CO2 emissions; therefore solid-based generation is massively displaced by gas-generation in the medium term. Demand for gas by the power sector is increased relative to the baseline over the same time horizon. Dependence on gas in the medium term and concerns with respect to security of supply are aggravated in the Supply Scenario. After 2020, however, dependence on gas is remarkably alleviated and coal-generation enabled with CCS regains a significant share in the power sector. However, total coal consumption is reduced from Baseline levels, because nuclear and renewables substitute for fossil fuels all together. Biomass plays an increasingly important role in thermal power generation: biomass generation ends up at 30% higher than baseline levels in 2050.

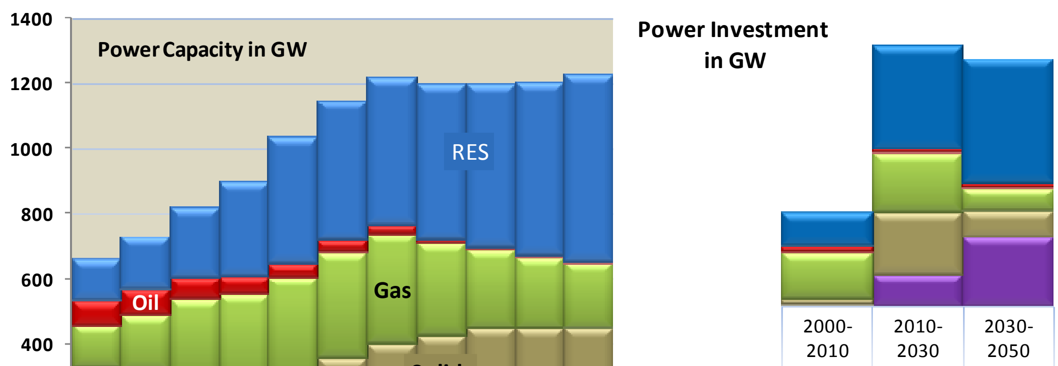
Total investment in renewables increases by 11% in the Supply Scenario relative to the Baseline. All RES technologies are equally increasing but the time profile of their development is very different. Mature technologies such as onshore wind and biomass develop more in the medium term rather than in the long term. Conversely, less economically mature technologies like solar PV and solar thermal (and tidal) mainly develop in the long term. In volume terms, the contribution of solar energy is remarkable in this scenario reaching levels of the same order of magnitude as power from offshore wind in the end of the projection period.

Figure 23: Supply Scenario EU25 - Investment in RES power



In terms of installed MW, half of total investment in the period 2030 to 2050 is in renewables, 28% in nuclear and the rest in CCS coal and gas. Investment before 2020 is mainly based on gas-fired power plants, but in the period 2020-2030 more balanced choice of fuels is observed.

Figure 24: Supply Scenario EU25 - Power Generation Capacity



	2000-2010	2010-2030	2030-2050
Renewables	90	278	330
Oil	16	11	11
Gas	125	159	61
Solids	15	164	73
Nuclear	4	87	184

Because of the absence of policies and technologies that would accelerate energy efficiency improvement in energy demand sectors, the changes that take place in the power sector are economically attractive in order to minimise total cost of emission abatement. In the Supply Scenario, carbon reducing options such as RES, nuclear and CCS are exploited close to their maximum economic potential. A shift in the fuel mix favouring the use of gas takes place in the medium term but this shift is reversed in the subsequent periods.

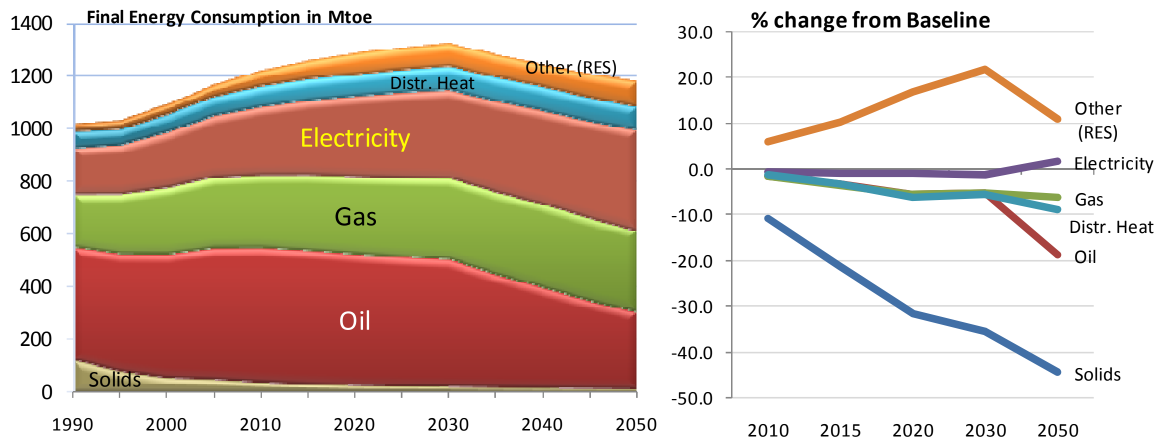
6.4. Effects on Demand Sectors

The marginal cost of emission abatement in the supply-side of the energy system is in general lower than in the demand-side, explaining why energy efficiency registers lower improvement. It follows, that it is beneficial for consumers to use more electricity as a substitute for fossil fuels, thus avoiding high marginal costs of emission reduction from additional energy efficiency measures. Displacing carbon reduction from demand-side to the supply-side of the energy system is found cost-effective.

This explains why electricity substitutes for fossil fuels in all final demand sectors. However, the lack of advanced electro-technologies - like those that are assumed to penetrate the market under the "Role of Electricity" scenario - limits the possibilities of further electrification.

Consequently the share of electricity in final energy demand is found to be higher than in the Baseline. By 2050, the share of electricity increases by 3% relative to the Baseline, reaching a share of 32% in final energy demand. By 2030, the market share of electricity is larger by 2% in industry and by 1.3% in the domestic sector. Such market penetration takes place mainly in thermal uses where electricity directly competes against fossil fuels. Demand for specific electricity uses is generally found reduced as a result of energy efficiency improvement. Electrification in transport is very limited.

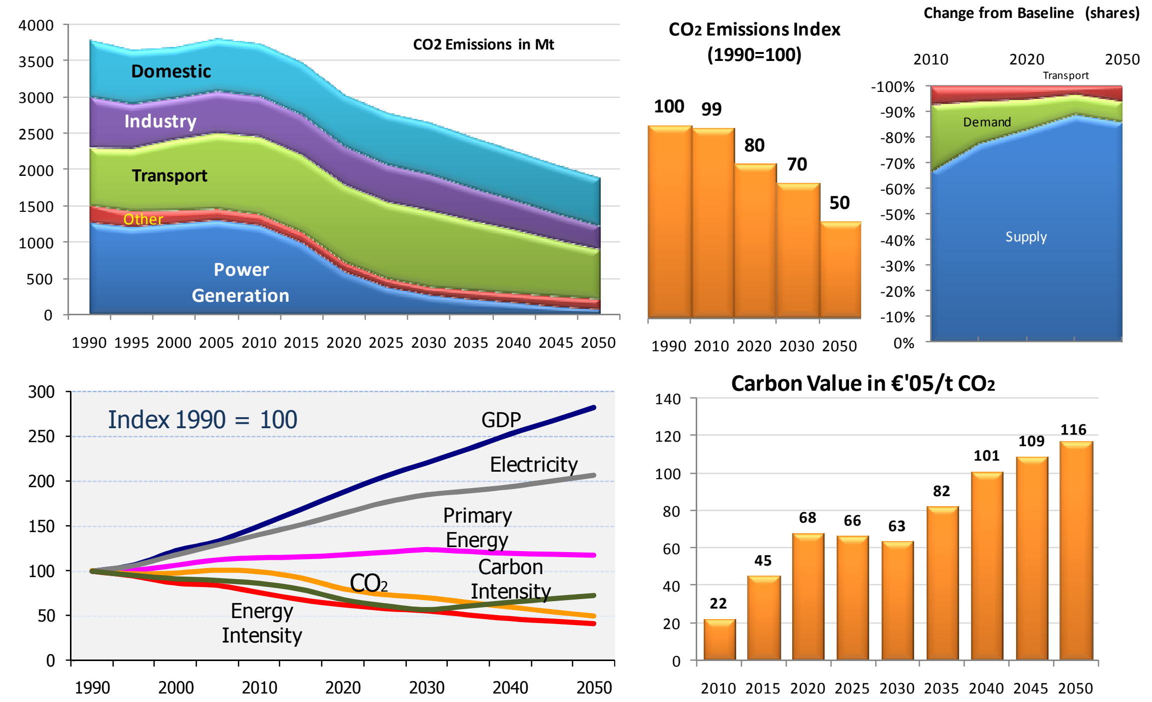
Figure 25: Supply Scenario EU25 - Structure of Final Energy Demand



6.5. Emission Reduction Indicators

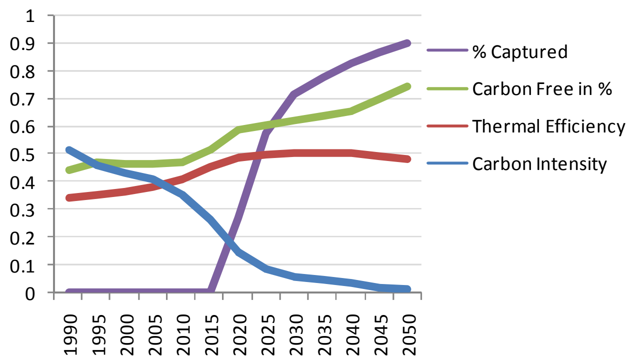
In summary, emission reduction is dominated in the Supply Scenario by energy supply emission abatement. The fact that the supply-side abatement options are used at high levels with respect to their economic potential implies high marginal cost of abatement.

Figure 26: Supply Scenario EU-25 - Indicators about CO2 Emissions



Consequently the Carbon Value is estimated to be high and increasing over time. Since the potential of carbon reducing options also develop over time, the time profile of the Carbon Value can be divided in three distinct periods: in the period to 2020 the Carbon Value increases as a result of exhaustion of possibilities to shift to gas; the new possibilities, such as CCS and nuclear, induce stabilisation and even a small drop of the Carbon Value in the period 2020-2035; as the use of these options approaches their potential and further development of renewables takes place, the Carbon Value increases again in the period 2035-2050.

Figure 27: Supply Scenario EU25 - Carbon Intensity Indicators

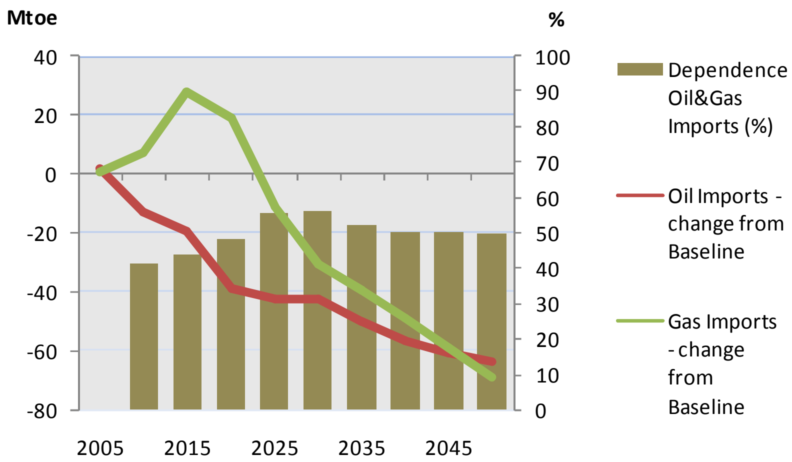


As already mentioned, the carbon emission reduction in the power sector is equally due to CCS and the development of carbon free resources, such as nuclear and renewables. The use of CCS implies lower thermal efficiency since additional energy is needed to capture CO2. Similarly, nuclear power needs additional energy for the treatment of nuclear fuel and waste. These secondary effects, which lead to higher use of energy in supply, have small, almost negligible effects, in comparison with total emissions saved by the corresponding technologies.

6.6. Impacts on Primary energy Supply

Both energy savings by demand sectors and the increased use of renewables and nuclear contribute to improving import dependence on oil and gas. The improvement is higher in the long term. Conversely in the short term more gas imports than in the Baseline are required. Import dependence on oil and gas is reduced by 3 percentage points in 2030 and by 10 percentage points in 2050.

Figure 28: Supply Scenario EU25 - Import Dependence Indicators



6.7. Implications on Costs and Prices

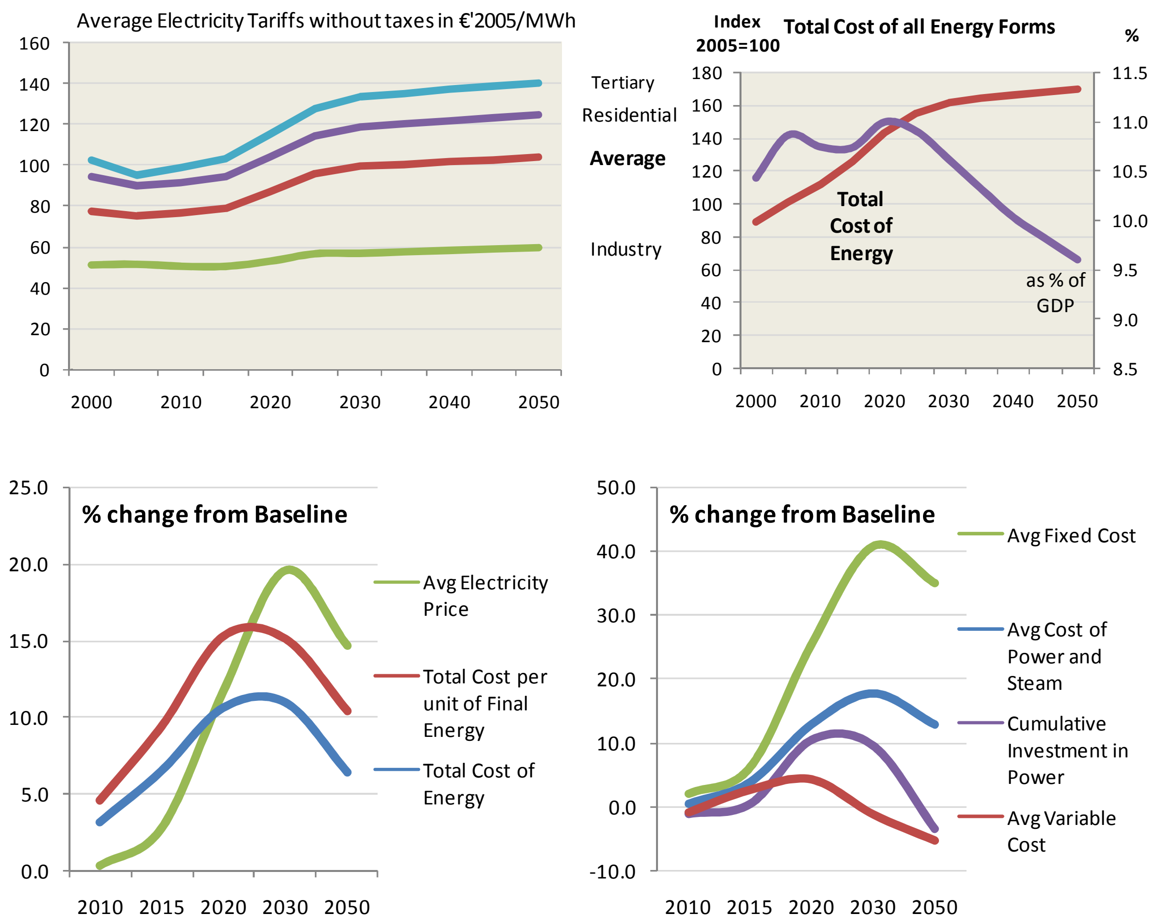
As expected, the imposition of emission restrictions induces higher energy costs and prices, compared to the Baseline. Additional costs arise from energy system restructuring. The rate of change of energy costs and prices relative to the Baseline shows a maximum between 2020 and 2035. The rate of change of costs and prices, albeit positive, decreases over time in the long term, as the new carbon-reducing technologies become mature and their costs benefit from scale and learning-by-doing effects.

The additional charge on consumers has a temporary profile; however it lasts for a long period of time. The additional cost of the energy system as percentage of GDP increases and represents 1% of GDP, which of course is considerable. The total cost of energy is 11% higher than Baseline levels in 2030, and 6.4% in 2050..

The average price of energy per unit of toe delivered to customers increases by 15% from Baseline in 2030 and by 10.4% in 2050.

Electricity prices also relative to the Baseline, ending up at 20% higher levels in 2030 and 15% in 2050 (in real terms). This reflects increases of electricity generation costs, the structure of which also changes on account of two factors: i) spending on fixed and capital costs increases considerably relative to the Baseline and ii) fuel costs decrease as a result of substituting capital for fossil fuels. Expenditure in power generation investment also rises relative to the Baseline driven by the fact that the new technologies are more expensive in capital terms and also that new power plants substitute for old plants instead of extending the lifetime of the latter.

Figure 29: Supply Scenario EU25 - Cost Indicators



6.8. Drawbacks of Supply Scenario

The Supply Scenario delivers the requested emission reduction by focussing on energy supply sectors and mainly on power generators. The contribution of other sectors is minor. The restructuring of power generation is substantial with respect to investment and the deployment of new technologies. However, emission reduction is based on few options which are exploited close to their potential. This raises concerns regarding risk of success. The developments induce significant improvement with respect to dependence on imported oil and gas but also imply high adaptation costs. Consumers are likely to face significant increases of energy prices and costs and the economy as a whole will have to spend 1% of GDP over a long period of time in order to meet the emission targets, under the conditions and options assumed for the Supply Scenario.

7. The Efficiency & RES Scenario

7.1. Introduction

For the *"Efficiency & RES" Scenario* it is assumed that the energy system in order to meet the overall emissions constraint mainly acts by promoting energy efficiency in the use of energy and the development of renewables. The scenario assumes the implementation of the restrictive nuclear policies applied in the Baseline. It is also assumed that Carbon Capture and Storage technologies do not develop.

Regarding energy efficiency it is assumed that a series of policy actions are fully and successfully implemented, including the EU Directives on building performance, the Directive on end-use energy efficiency and energy services and the eco-design Directive. As a result, efficiency improvements are more important in the household and services sector and also in relation to the use of energy equipment and appliances in all sectors. For transport, it is assumed that structural measures are put in place and new infrastructure is developed leading to a substantial increase in the use of public transport which substitutes for individual car use. In addition cogeneration of heat and power is promoted and the EU BAT Directives drive investment in state-of-the-art new energy plants, with respect to their energy performance.

For the "Efficiency & RES" scenario it is also assumed that as a result of the above policies and possible campaigns, energy consumers become more aware about the benefits from energy efficiency and follow rational use of energy practices. In addition, mainly as a result of a wide-spread support of efficient appliances the consumers change their perception of energy costs and the risks associated with the adoption of advanced technologies, so they take advantage of cost-effective and energy efficient solutions in their purchase and investment choices. Energy efficiency labeling is instrumental in this respect. Other ongoing action at the EU, national and local level, such as RTD policy, regional and cohesion policy as well as transport restructuring policy contribute to improved energy efficiency.

As a result of the above policies, useful energy (energy services such as heat, light, cooling, motion, industrial processing) is supplied in a more efficient way following consumer choices opting for energy equipment with advanced efficiency characteristics also brought about by efficiency standards that force the least efficient energy consuming variants out of the market. In addition high standards in the construction of buildings and undertaking of renovation works lead to significant gains in terms of thermal integrity and reduce heating and cooling requirements.

The model simulates the above changes as an increase of the potential for cost-effective energy efficiency improvement in all processes and energy demand sectors of the economy. The drive for accelerating the adoption of the advanced efficiency options is the reduction of CO2 emissions. The model determines endogenously the degree at which consumers practice rational use of energy and adopt advanced technologies that enable energy efficiency improvement.

As a consequence of higher potential of energy efficiency improvement, the marginal cost of energy efficiency improvement becomes cheaper than in the Supply Scenario and therefore consumers tend to increasingly adopt measures that reduce demand for energy. In order to achieve the emission reduction at the level of the entire energy system, the increasing optimality of measures in demand sectors lead to using measures in the supply side at a lower level than in the Supply Scenario. This rebalancing of measures between demand and supply sectors is also accentuated as a result of the assumption that for the "Efficiency & RES" scenario the options for removal of nuclear constraints and development of CCS are not considered.

Apart from the energy efficiency, the scenario also considers high promotion of renewables. The deployment of renewable energy technology at large scale faces a multitude of obstacles which are increasing both their effective development cost and the risk perceived by investors. A policy promoting renewables can be very effective in removing barriers that obstruct development of renewables at large scale. Such policy may include actions to facilitate licensing, land use, connection to grid, industrial production of materials and equipment, security in capital earnings and financing, etc. Instruments such as the feed-in tariffs, the green certificates, the certification of electricity origin and other of similar nature contribute to remove risk of earnings from production of renewables. Other measures, such as the installation of digital meters, the facilitation of architectural designs and the promotion of O&M networks help to promote renewables development at the scale of individual consumers.

In economic terms, all these measures increase the volume of cost-effective potential of renewables and incite consumers and investors to lower their perceived cost of technology and their subjective risk associated with investment decisions. Consequently, they tend more to opt for renewables.

Agricultural policies have also a great role to play in promoting the use of biomass as a source of energy. Measures and plans that develop agricultural infrastructure that organize and standardize the production, conditioning and distribution of biomass-related commodities allow for increasing returns to scale and therefore reduce the cost per unit of energy delivered by biomass.

Economies of scale have been identified as a major driver of biomass development. Their achievement heavily depends on the re-orientation of agricultural policy in Europe and the adoption of an effective long term supportive plan. Such policy, which is assumed to take place for the "Efficiency & RES" scenario, leads to an increase of the economic potential of biomass as a source of energy.

Other policies, which are also assumed to be adopted for the "Efficiency & RES" scenario, promote the use of wastes as source of energy. Similarly, the cost-effective potential of waste is assumed to increase as a result of these policies.

Regarding renewables, no additional subsidies to RES are assumed for "Efficiency & RES" Scenario. The additional policies facilitate the exploitation of larger potential of RES in economic terms.

Therefore, for an emission constrained scenario, as the "Efficiency & RES", the renewables are adopted more than in other scenarios for carbon emission abatement.

7.2. Effects on Energy Demand

As a result of promoting energy efficiency, final energy consumption decreases in all sectors. Compared to the Baseline, the decline in final energy consumption is of the order of 13% in 2030 and 22% in 2050.

The tertiary sector achieves higher reduction of energy consumption: 20% from Baseline in 2030. Industrial energy consumption decreases more in the long term and mainly beyond 2030. The transport sector displays a similar time profile in terms of consumption decrease.

This result reveals that long lead time is needed for the restructuring in industry and transportation. The decrease of energy consumption by households is more uniform over time and does not exceed 15% from Baseline.

Total final energy consumption in 2035 becomes equal to its level in 2005 and further declines in 2050, becoming equal to its 2000 level.

Figure 30: Efficiency & RES Scenario EU25 - Change of Energy Demand by Sector from Baseline

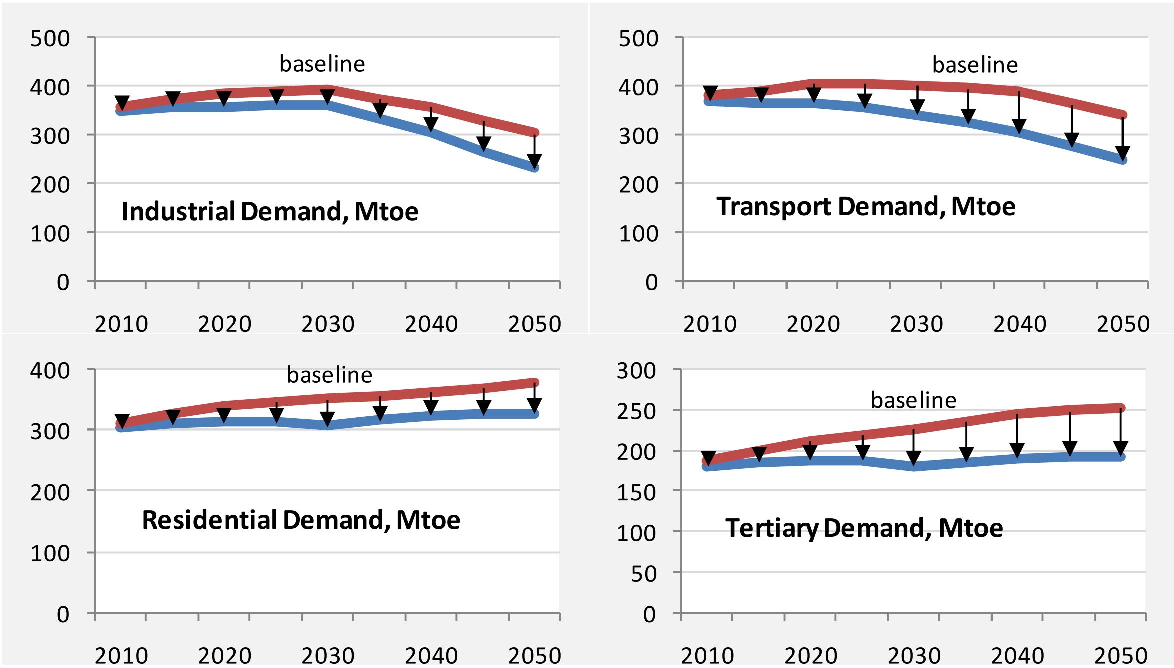
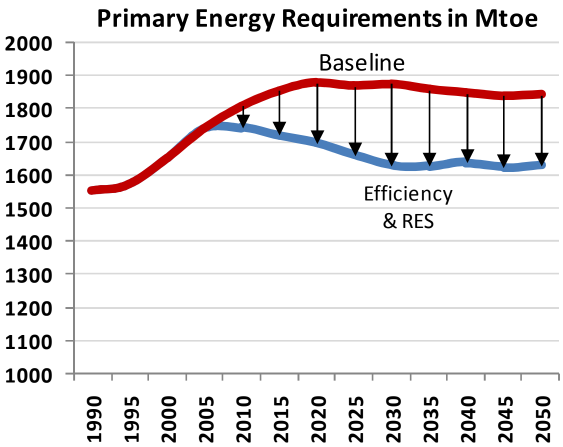


Figure 31: Efficiency & RES Scenario EU25 - Total Primary Energy



The average annual rate of change of the overall energy intensity goes down by 1.7% in the Baseline scenario and by 2% in the “Efficiency & RES” Scenario. In addition, from 2010 onwards, total primary energy requirements of EU25 decrease continuously over time and attain in 2050 a level comparable to their level prior to 2000.

For 2020 it is found that the EU25 could reach the level of 1697 Mtoe in terms of total primary energy requirements which is close to the level considered by the European Commission as a target for energy efficiency policy. The “Efficiency & RES” Scenario illustrates that a remarkable performance in terms of total primary energy can be obtained if an ambitious energy efficiency policy portfolio is successfully implemented and if it is combined with a stringent emission reduction constraint.

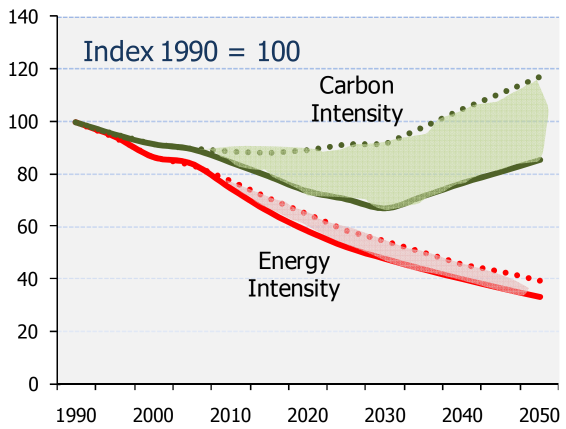
Concerning the fuel-mix of final energy consumption, all energy forms exhibit a downwards trend under the “Efficiency & RES” Scenario, with the exception of renewables and distributed heat/steam which increase over time. Consumption of fossil fuels in end-uses declines considerably from baseline: -18.6% in 2030 and -34.1% in 2050 for oil products, and -14.4% in 2030 and -28.4% in 2050 for natural gas.

Demand for electricity decreases from Baseline between 12 and 13% in the period 2030-2050, but it gains a higher market share in final demand. Electricity substitutes for other energy forms. This suggests that under "Efficiency & RES" it is optimal to displace part of emission reduction from demand sectors to power generation.

However, the reduction of total energy demand is higher than the substitution effect and electricity demand is found lower than in baseline. Electricity used in specific electrical uses decreases more than electricity used in thermal uses. Electricity savings are found higher in the tertiary sector and particularly in specific electrical uses. Electricity demand in industry is far less affected. The "Efficiency & RES" Scenario does not assume successful development of advanced electro-technologies, for example plug-in hybrid cars and highly efficient heat pumps, as is the case of the "Role of Electricity" scenario. This assumption limits the potential of electricity for further substitution for fossil fuels in thermal uses and in transportation.

7.3. Effects on Renewables

Figure 32: Efficiency & RES Scenario EU25 - Changes of Indicators from Baseline

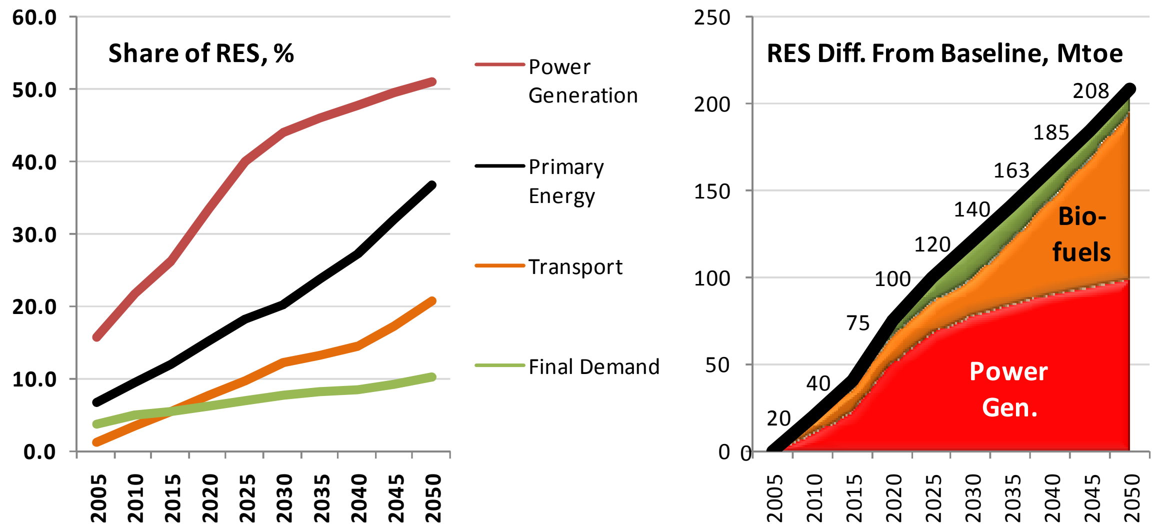


The remarkable improvement of energy efficiency and the resulting decrease of energy demand are not enough to curb CO2 emissions to the extent required for the "Efficiency & RES" Scenario. In order to meet the target, the carbon intensity also has to drop from Baseline. The results show that the changes of the latter are larger than the decline of energy intensity; hence it is found that the development of renewables and other restructuring of energy supply away from carbon intensiveness contribute more than energy efficiency in total emission reduction.

Indeed, the "Efficiency & RES" Scenario shows a remarkable growth of renewables in the European energy system.

In power generation the RES is by far the fastest growing source of electricity as it acts as a substitute for fossil fuels, mainly for solid fuels. The share of RES generation in the power sector reaches 45% in 2030. In 2050 one out of two kWh is produced with RES.

Figure 33: Efficiency & RES Scenario EU25- Growth of Renewables



The bio-fuels also penetrate the transportation market reaching a share of 24.6% in road transportation by 2050. In general, the growth of biomass uses is faster in the period between 2030 and 2050, because the biomass supply infrastructure needs long lead time to develop.

The RES also develop in end-uses, mainly for heating purposes. The RES facilitates the development of CHP and district heating which develop more than in Baseline.

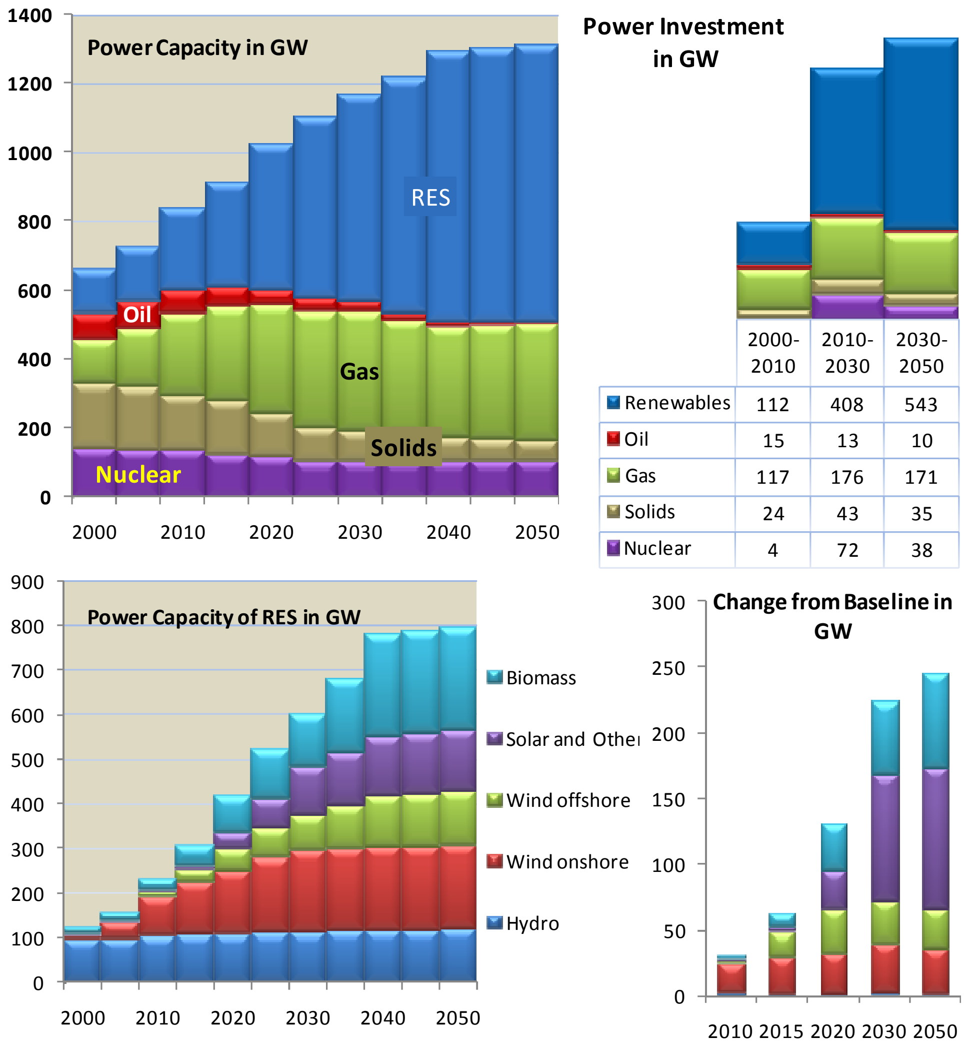
The development of power generation capacity is dominated by RES-power investment. In the period 2010 to 2030, more than one of two new MW of power capacity constructed is RES-power. In the period beyond 2030, 66% of capacity expansion is based on RES. This result is of course driven by the stringent CO2 emission restriction assumed for this scenario; but it is so also because RES electricity is increasingly competitive in the long term as a result of policies that facilitate the development of biomass and generally the infrastructure that enables economies of scale and learning-by-doing.

Wind power capacities, both onshore and offshore, increase from Baseline and their development approaches their potential.

The most noticeable change from Baseline is the development of biomass-firing power generation and solar electricity. They both develop mainly in the longer term, especially in the period beyond 2025. Their development peaks around 2040 and stabilises thereafter.

In terms of power generation, intermittent renewables (wind, solar, tidal, etc.) from 16% share in total power generation by RES in 2005 get a share just above 40% by 2020 and stay at that level until the end of the projection period. Power generation from biomass grows slowly in the early projection years but its pace becomes faster in the long term.

Figure 34: Efficiency & RES EU25 - Power Generation Capacity

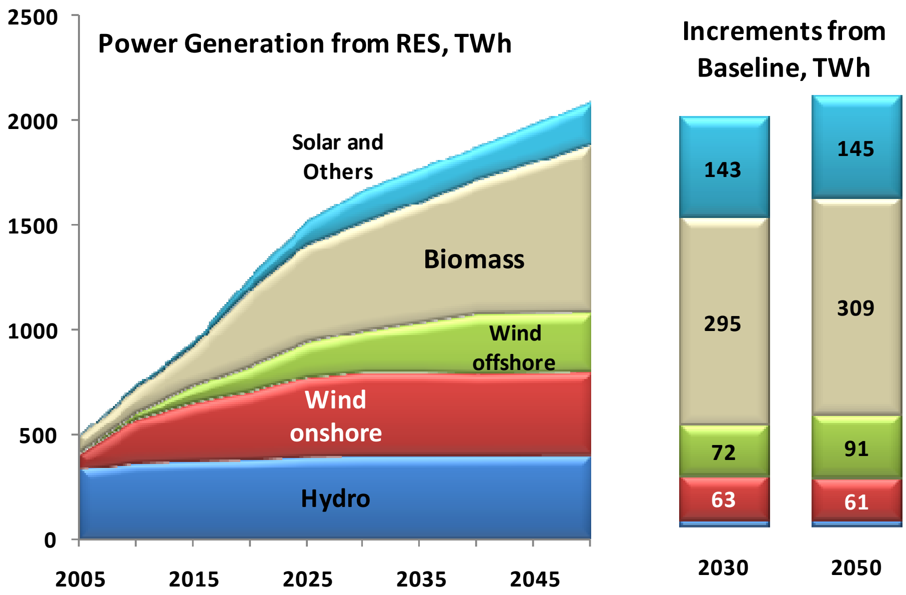


	2000-2010	2010-2030	2030-2050
Renewables	112	408	543
Oil	15	13	10
Gas	117	176	171
Solids	24	43	35
Nuclear	4	72	38

Compared to the Baseline, the large incremental changes of RES power generation can be attributed to the development of biomass and solar energy. The growth of the former challenges upstream biomass supply industry and of the latter requires the development of highly distributed grid systems. Power generation from intermittent renewables sources despite figuring with a small share (2.7%) in total power generation in 2005, grows considerably in the outlook, reaching shares of up to 20% in 2030 and 22% in 2050; this development also challenges power grid technologies and requires grid reinforcing investment.

At the level of the entire energy system, the renewable energy sources as developed for the "Efficiency & RES" scenario represent 20% of total primary energy requirements in 2030 and 36.8% in 2050. Regarding year 2030, this share is in line with the renewables target as proposed by the European Commission. The driver, apart from the facilitation policies, is the stringent CO2 emission target.

Figure 35: Efficiency & RES EU25 - Power Generation from RES



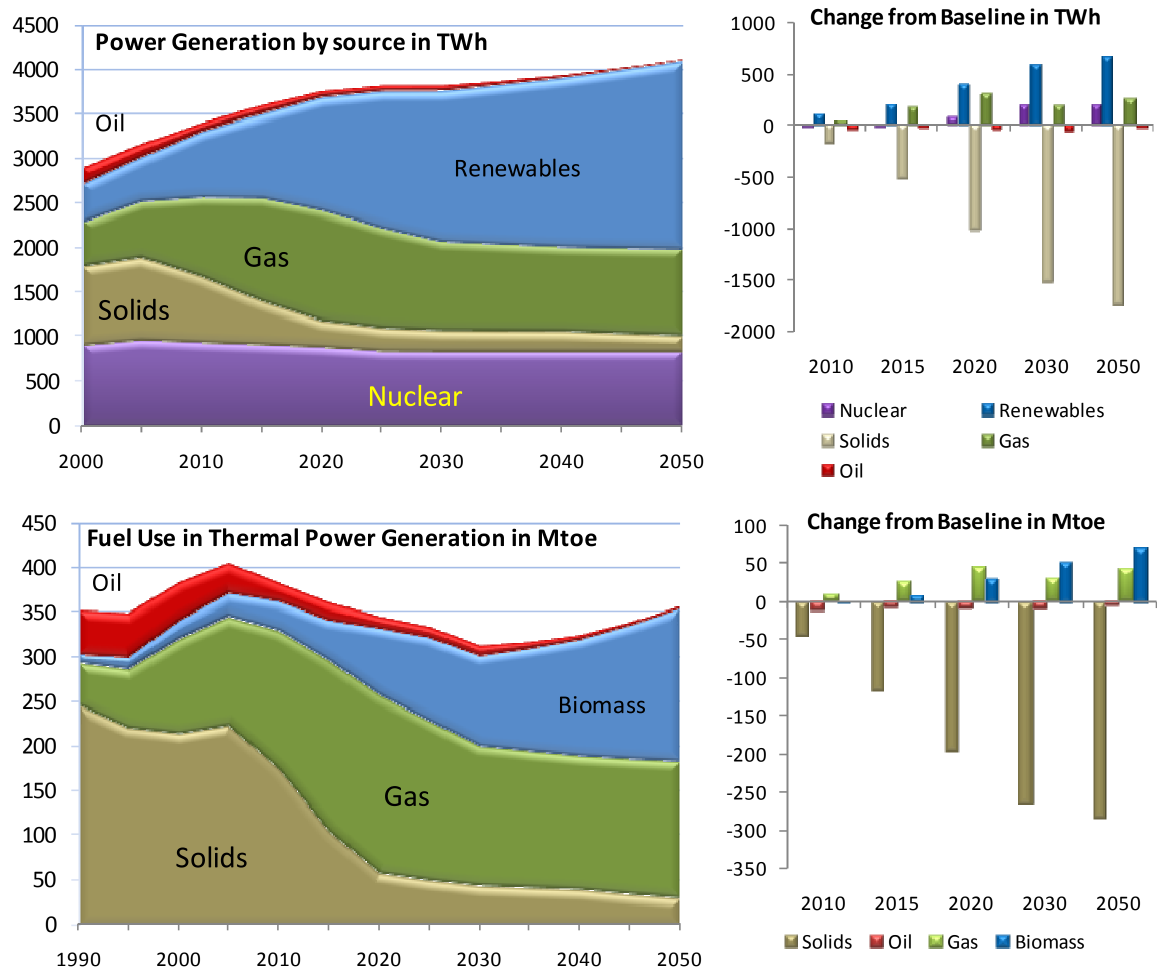
7.4. Power Sector

Apart from renewables, the development of the power generation sector is very different relative to both the Baseline and Supply scenarios. The overall energy system, bound by the constraint to reduce CO2 emissions but without being able to resort to reductions in the demand for energy, is forced to restructure power generation not only by exploiting more renewables but also by utilising low carbon sources to the largest extent possible. But the lack of nuclear freeing policy, which was assumed for the Supply Scenario, and the absence of CCS technology, forces power generation to massively invest in gas-fired power technologies.

As a result, gas-based generation increases from Baseline by 30% or more during the entire projection period. Gas substitutes for coal in power generation, the latter bearing a strong decline leading to a mere 6% share in 2030 and 4% in 2050. In the period 2025 to 2050, gas-based generation is more than double from the Supply Scenario.

The time period 2015 to 2030 is marked by thermal generation relying on gas. Beyond 2030, further gas use is limited as biomass-based sources develop at fast pace and cover incremental needs for thermal generation. However, as a result of total electricity production being lower from Baseline driven by energy savings in demand sectors, the additional gas requirements are rather moderate: 40 to 60 Mtoe of gas is needed annually in addition to the Baseline for the period 2020 to 2050. In view of gas supply threats or insecurity, the additional demand for gas is an issue for further consideration. In the long term, gas demand by power generation stabilizes at an amount of 150 Mtoe per year, which is comparable to the consumption projected for the EU-25 in 2010. This is 40 Mtoe higher than Baseline levels for the longer term, which corresponds to a 40% increase.

Figure 36: Efficiency & RES EU25 - Structure of Power Generation



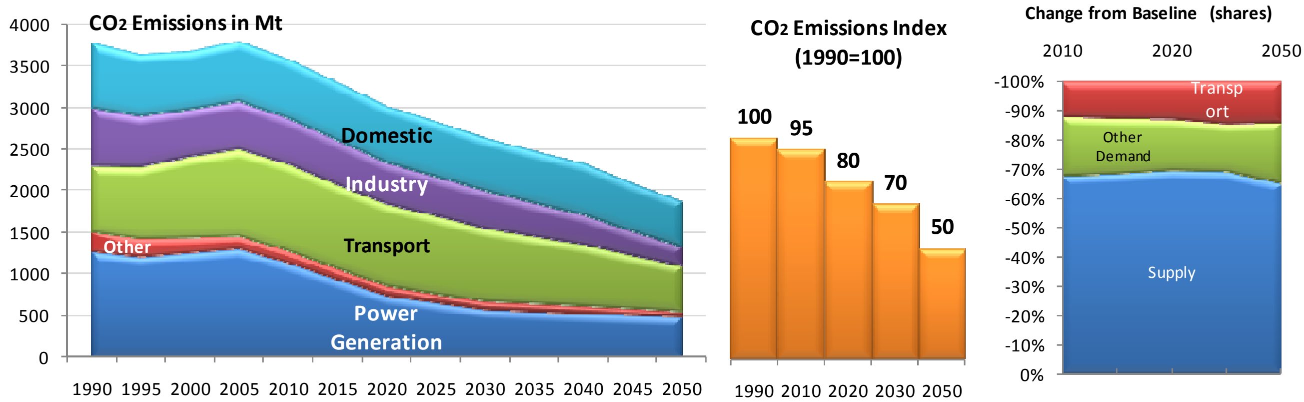
Although this scenario assumes that no revision of nuclear policy takes place (an assumption also underlying the Baseline Scenario) nuclear energy is found to be 30% higher than in the Baseline for the period beyond 2025. Total nuclear investment amounts to 114 GW for the entire projection period that is 27.5 GW up from Baseline. Extension of lifetime of old nuclear plants is not assumed to apply in the "Efficiency& RES" Scenario. Accordingly, this additional investment allows nuclear to maintain a constant share of about 21% in total power generation (up from 14% in the Baseline Scenario).

The power generation sector under the "Efficiency & RES" Scenario transforms into a very low carbon intensive energy conversion system.

Carbon intensity is equal to 0.15 tCO2/MWh in 2030 and to 0.12 in 2050, which is three times lower than in Baseline, but 6 times higher than in the Supply Scenario.

However, given that also the demand sectors undergo considerable change with respect to their energy efficiency their contribution to curbing CO2 emissions is important and remains higher than 30% of total reduction from Baseline.

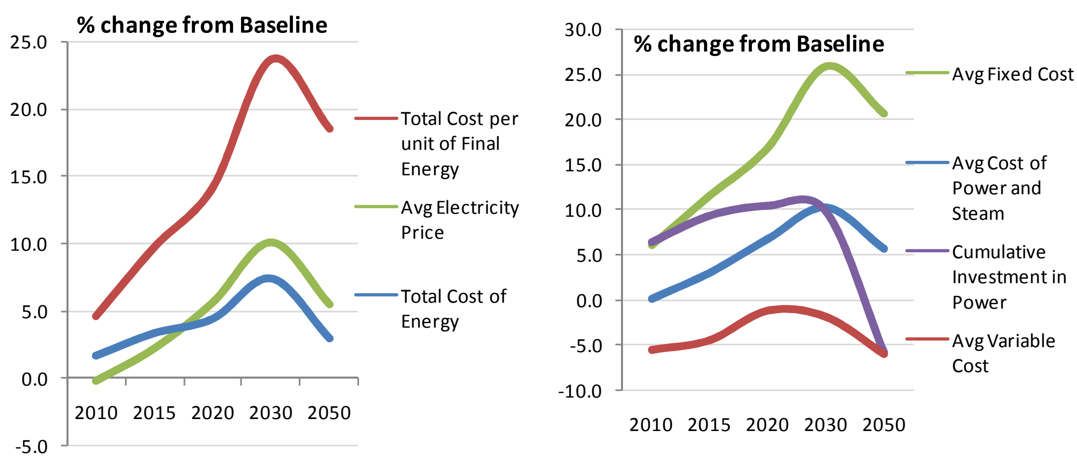
Figure 37: Efficiency & RES Scenario EU25 - Structure of CO2 Emissions



7.5. Implications on Costs and Prices

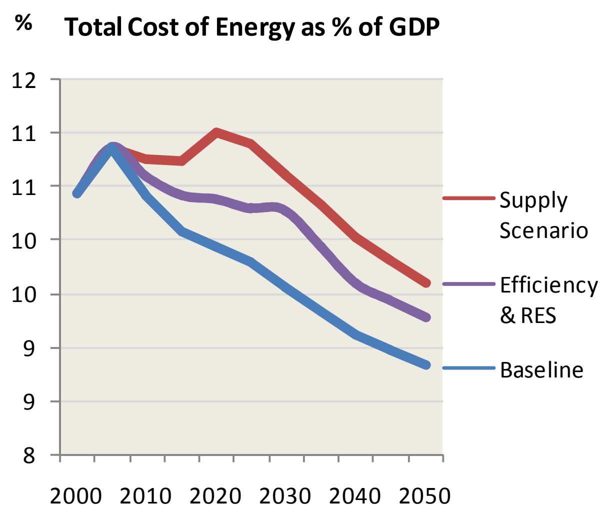
Conversely, average electricity prices that were found to be 20% higher than the Baseline in the Supply Scenario (in 2030) are only 10% higher than the Baseline in the "Efficiency & RES" scenario (in 2030). Average fixed and capital costs per unit of electricity that increased by 40% in the Supply Scenario relative to the Baseline (in 2030), only increase by 25% in the "Efficiency & RES" scenario. Average variable costs per unit decline relative to the Baseline in both scenarios.

Figure 38: Efficiency & RES Scenario EU25 - Energy Costs and Prices



Although the "Efficiency & RES" implies lower electricity costs then the Supply Scenario it involves higher energy costs at the level of the entire energy system. In the "Efficiency & RES" Scenario the demand sectors undertake a considerable part of total emission reduction, which was not the case in the Supply Scenario. It follows that non electricity energy costs become larger in the former than in the latter scenario. In the "Efficiency & RES", the total unit cost of final energy in 2030 is 25% higher than in the Baseline, whereas the respective increase in the Supply scenario was 16%.

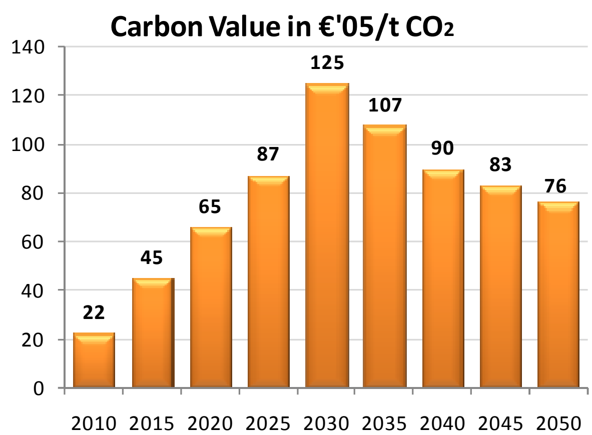
Figure 39: Efficiency & RES Scenario EU25 - Total Cost Implications



Nevertheless the comparison of "Efficiency & RES" with the "Supply Scenario" with respect to the total energy cost as percentage of GDP shows that the former is clearly more cost-effective than the latter. This result confirms that priority must be given to energy efficiency progress in the demand-side of the energy system. The new supply technologies, like advanced nuclear and CCS, can deliver emission reduction but in terms of cost implications they need to be complemented with extensive efficiency measures in the demand sectors.

Figure 40: Efficiency & RES Scenario EU25 - Carbon Value

The carbon value for the "Efficiency & RES" peaks in 2030 and decreases thereafter, yet remaining at rather high levels. The decrease beyond 2030 is mainly driven by the increasing economies of scale and learning-by-doing that the renewables are experiencing in association with their massive deployment. Until 2030, energy efficiency progress is exploited at a high level compared to its potential, so marginal costs increase. The same takes place for renewables before 2030. The slowness of developing efficient infrastructure for renewables, particularly for biomass, explains why the scale effects effectuate reduction of marginal costs mainly in the long term.

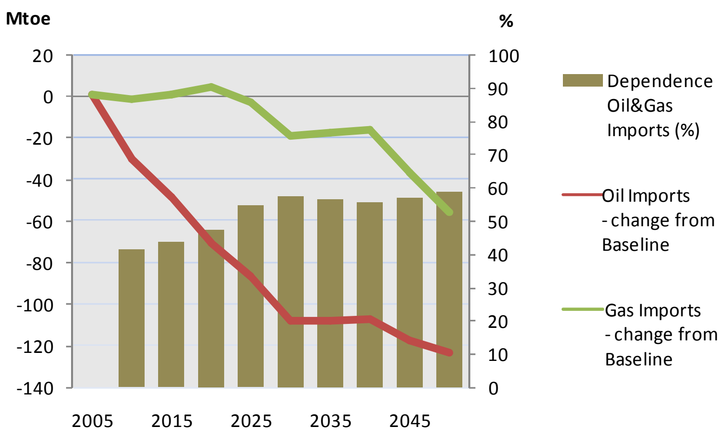


7.6. Primary Energy Demand and Supply

The emission reduction by the demand sectors exceeds a share of 30% in total reduction throughout the projection period. Changes in transportation contribute by 12% in total reduction. As a result of reduction of energy demand, the "Efficiency & RES" Scenario induces significantly lower requirements for primary energy than the Baseline. As already mentioned total primary energy requirements continuously decrease over time after 2010. In addition the restructuring of the energy system energy system towards the promotion of renewables leads to a further reduction in the demand for fossil fuels.

Total primary energy from solid fuels declines in the long term by 4 or 5 times from their level in 2005. Solid fuels have a negligible share in the EU energy balance after 2020. This of course affects both indigenous production and imports of solid fuels.

Figure 41: "Efficiency & RES" Scenario EU25 - Import Dependence



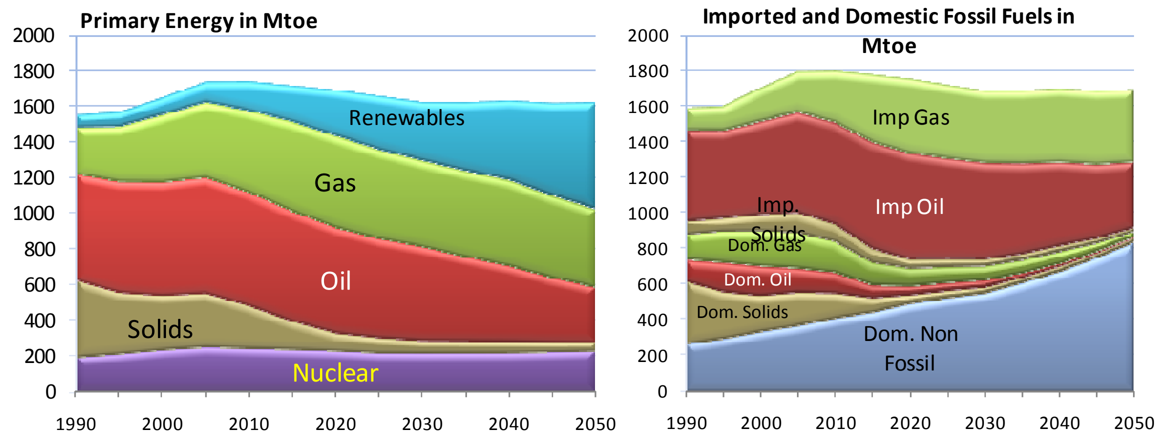
Oil imports are also considerably lower in the "Efficiency & RES" scenario, and reduce over time; they reach in 2050 a level 35% down from 2005. Despite the reduction in final energy demand, the increasing use of gas in power generation leads to gas imports that are slightly lower than in the Baseline but significantly higher than in the Supply Scenario.

Dependence on gas imports under the "Efficiency & RES" Scenario raises concerns regarding the sustainability of the type of restructuring suggested by this scenario. The efficiency improvement is not sufficient to reduce dependence on gas imports. For this purpose, complementary changes in the supply-side, similar to the changes occurring in the Supply Scenario, would be needed to complement the demand-side improvements.

Net imports of gas, under the "Efficiency & RES" scenario, increase from 2005 as it was also the case in both the Baseline and the Supply Scenarios. Compared to the latter, the "Efficiency & RES" involves additional net imports of the order of 20 to 30 Mtoe per year, which represents 8% increase from the Supply Scenario.

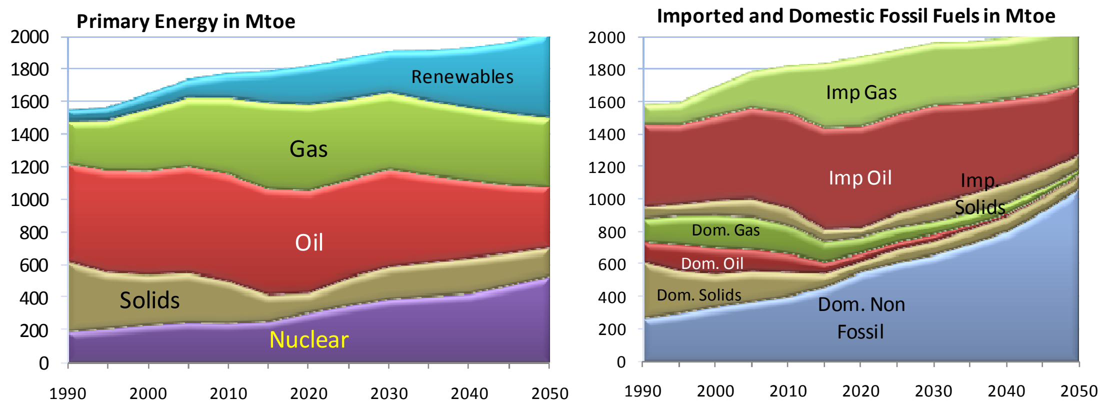
The outlook of primary energy supply and demand of the EU25 in the "Efficiency & RES" Scenario, despite the persisting dependence on gas imports, shows remarkable change from Baseline: the indigenous mainly renewable and secondarily nuclear resources succeed to cover more than 50% of total energy needs in 2050.

Figure 42: Efficiency & RES Scenario EU25 - Primary Energy Demand and Supply



It is interesting to compare this outlook to the one resulting from the Supply Scenario. They differ of course with respect to total energy requirements, as in the Supply Scenario demand is increasing, whereas in the "Efficiency & RES" demand is decreasing.

Figure 43: Supply Scenario EU25 - Primary Energy Demand and Supply



However, the share of indigenous resources in total demand follows a similar, increasing pattern, but the main contributor is nuclear energy in the "Supply Scenario" and renewable energy in the "Efficiency & RES" Scenario. Both scenarios show a persisting dependence on gas imports, reduce oil imports and involve considerable decline of coal, even in the Supply Scenario in which CCS develops.

8. The "Role of Electricity" Scenario

8.1. Introduction

The "Role of Electricity", contrary to the other alternative scenarios, is designed so as to combine all possible carbon-reducing means, without any exclusion whatsoever.

Similar to the "Efficiency & RES", it is assumed for the "Role of Electricity" that policies and technological developments take place which are favourable to higher energy efficiency in the demand sectors. As a result, consumers perceive lower cost of advanced energy technologies and modify their choice of durable goods and energy processing equipments. For the "Role of Electricity" Scenario it is assumed that the potential for cost-effective energy efficiency improvement increases from Baseline. This concerns all kinds of energy processes and all energy demand sectors. In addition, the policies and measures that promote rational use of energy, as taken into account for the "Efficiency & RES" Scenario, are also included in the "Role of Electricity". Higher use of public transportation means, better insulated buildings and generally behaviours that use energy in a more rational way are among the structural changes considered for the "Role of Electricity" Scenario.

It must be noted, however, that all the above policies and measures facilitate consumers in making decisions resulting to improved energy efficiency, but the degree to which consumers will effectively select the advanced technologies and will save energy is endogenously determined by the model. This depends on economic optimisation: the consumer, in optimising his individual decision making, takes as given the marginal cost of overall emission reduction, i.e. the Carbon Value. If changes in energy supply facilitate the achievement of the overall emission reduction target, the Carbon Value is reduced. Therefore, for the consumer, it is optimum to undertake less carbon reducing actions and hence reduce his energy saving effort. In other words, the consumer perceives lower carbon cost associated with his energy consumption and consequently consumes more than expected[6].

[6] This effect is similar to the "rebound" effect which is studied in the literature, defined as a revenue-effect of energy saving measures leading to higher demand than expected by engineering studies. It is a revenue-effect because energy savings allow for an increase in disposable income.

Since the "Role of Electricity" Scenario assumes availability of all carbon reduction means, in both the demand and supply energy sectors, the energy efficiency gains are expected to be lower than those obtained in the context of the "Efficiency & RES" Scenario.

Concerning the promotion of renewables, the "Role of Electricity" Scenario involves policies and measures similar to the "Efficiency & RES" Scenario. As a consequence, barriers to the development of renewables are removed and investment is facilitated. The policies and measures do not include higher subsidisation rates for renewables.

Given that within the "Role of Electricity" Scenario a larger set of carbon reduction options is available, it must be expected that the model will suggest development of renewables at a lesser degree than in the "Efficiency & RES" Scenario.

The two scenarios differ in their assumptions regarding the development of biomass. In fact, contrary to the "Efficiency & RES" Scenario, the specific policies that aim at promoting large scale use of biomass for energy do not take place within the "Role of Electricity" Scenario. Similarly, the re-orientation of agricultural policies is not implemented in the "Role of Electricity" Scenario.

Regarding the supply-side of the energy system, for the "Role of Electricity" it is assumed that both the removal of policy restrictions on nuclear energy and the development of CCS take place. In this respect the assumptions are identical to those adopted for the "Supply Scenario":

- Regarding nuclear energy it is assumed that the phase-out in three member-states is cancelled, the extension of lifetime of old nuclear plants depending on technical and safety standards is possible and countries that never had nuclear generation do not develop nuclear energy.

- Regarding CCS it is assumed that technology reaches maturity as a result of learning-by-doing and that transportation and storage of CO_2 are facilitated by the development of adequate infrastructure throughout Europe. The potential of CO_2 storage exhibits diminishing returns and involves increasing marginal costs.

The model optimises the degree of recourse to nuclear energy and to CCS by taking into account that, contrary to the "Supply Scenario", other carbon reducing options are also available. Therefore, it is not imperative that within the "Role of Electricity" nuclear and CCS develop as much as in the context of the "Supply" Scenario.

Apart from the carbon reducing means, which are also assumed for the other two scenarios, the "Role of Electricity" Scenario involves advancement of new electro-technologies. It is assumed that these technologies reach technical and economic maturity in connection with the degree to which they penetrate the market. They benefit from learning-by-doing and from development in large scale, and therefore they constitute options for consumer's decision making in addition to other advanced energy technologies.

The technological assumptions made for the "Role of Electricity" Scenario are based on specific engineering analysis carried out in another section of the present study.

The advancement of electro-technologies enables two mechanisms:

- First, they induce savings of electricity in specific electricity uses, like for example lighting, motor drives, etc.
- Second, they induce energy efficiency improvement and electricity substitution for fossil fuels in thermal or motion energy uses, where electricity competes against fossil fuels. Examples are heating and cooling of buildings, low enthalpy heat uses in industry and transportation vehicles.

Advanced heat pumps enable the second mechanism: by extracting ambient renewable heat or cold, they can indeed cover the heating or cooling needs of a building significantly more efficiently than conventional direct combustion of fossil fuels. Through advanced heat pumps, electricity substitutes for fossil fuels and at the same time total energy consumption decreases. The advanced heat pumps are represented in the model within the menu of technologies which may be selected by consumers in order to optimise their demand behaviour. Contrary to the other two alternative scenarios, for the "Role of Electricity" Scenario it is assumed that technologies such as the advanced heat pumps follow a high gradient of learning-by-doing.

The plug-in hybrid cars, buses and trucks enable a similar mechanism. They allow for the possibility to improve energy efficiency of transportation. They also enable increased use of electricity in the transport sector. Contrary to the other two alternative scenarios, for the "Role of Electricity" it is assumed that the infrastructure and the electricity market arrangements that facilitate market penetration of plug-in hybrid cars are put in place. It is also assumed that the battery technology progresses at a sufficient degree to facilitate the development of pure hybrid cars in plug-in hybrid cars.

The electro-technologies acting in demand sectors are complemented by transformation of power generation in order to attain a low carbon intensiveness level. The results indicate that this combination leads to a reasonable reduction in emission costs.

8.2. Market penetration of the new electro-technologies

Demand for energy by end-use sectors undergoes significant change in the context of the "Role of Electricity" Scenario. The overall cap on CO2 emissions incite the sectors to improve energy efficiency, save energy, modify the mix of energy forms and fuels and invest in more advanced end-use energy appliances and processes.

The results of the model show that in the context of the scenario the influence of new electro-technologies is considerable in all demand sectors.

Table 3: "Role of Electricity" EU25 - Industrial Energy Consumption

	Baseline Scenario (% of total final energy)			Role of Electricity	
Industry	**2005**	**2020**	**2030**	**2020**	**2030**
Thermal Processing	37.4	33.9	31.6	32.5	31.6
- Electricity	1.0	1.2	1.4	1.3	1.5
Steam and Heat	35.5	37.5	39.0	37.6	37.6
- Electricity	0.04	0.03	0.02	1.46	3.44
Electric Processing	14.2	15.3	15.7	16.2	16.5
Other specific Electricity	12.9	13.3	13.8	13.7	14.4
Total Electricity	28.2	29.9	30.9	32.7	35.8
- of which specific	27.1	28.6	29.5	29.9	30.9
- of which substitutable	1.0	1.3	1.4	2.7	4.9

	Baseline Scenario			Role of Electricity	
Consumption	**2005**	**2020**	**2030**	**2020**	**2030**
Total Energy (Mtoe)	339	383	393	360	367
Electricity (TWh)	1111	1331	1413	1368	1465
Efficiency (% change from 2000)	**2005**	**2020**	**2030**	**2020**	**2030**
Total Energy	1.0	9.3	18.2	13.9	24.7
Specific electricity	0.5	6.4	11.2	8.7	13.0
Electric Processing	0.9	11.3	21.8	14.5	24.9

In industry, taken as a whole, the use of electricity in Baseline Scenario is between 28 and 30% of total energy consumption. Electricity is used almost exclusively in specific electrical uses, mainly in electric processing.

Driven by the overall cap on CO2 emissions, the model results show that industry consumes 6% less energy than in the Baseline in 2020, 7% less in 2030 and 8% less in 2050. The decrease of consumption is lower in "Role of Electricity" than in "Efficiency & RES" Scenario, especially beyond 2030, but it is significantly larger than in "Supply Scenario".

The notable difference of "Role of Electricity" from the other two scenarios is that the electro-technologies allow electricity to substitute for fossil fuels at a significantly higher degree. The heat pumps, for example, allow electricity to penetrate the low enthalpy heat uses and attain a share of 3.4% within total steam and heat uses in industry, instead of a negligible share in Baseline. In addition, compared to Baseline more electricity is used for industrial processing.

Electro-technologies also induce higher energy efficiency in both thermal and specific electrical uses. Regarding heat uses, the efficiency index increases from the Baseline and becomes two times higher by 2030. The "Role of Electricity" Scenario shows that in 2030 20% of energy for heat uses is saved on top of energy savings obtained by the "Efficiency & RES" Scenario for the same year. The energy savings in specific electrical uses are due to the electro-technologies and are comparable to the savings obtained in the "Efficiency & RES" Scenario, even though in the latter most of carbon reducing changes take place in the energy demand sectors.

Total electricity consumption in industry increases from the Baseline. Electricity gains 5% additional share in total industrial energy demand. Electricity demand in industry in 2030 is 9% up from "Efficiency & RES" Scenario. The combined effect of the cap on emissions and the availability of electro-technologies lead industry in year 2030 to improve energy efficiency by 35% from Baseline Scenario and by 9% from "Efficiency & RES".

Table 4: "Role of Electricity" EU25 - Domestic Energy Consumption

	Baseline Scenario (% of total final energy)			Role of Electricity	
Domestic	**2005**	**2020**	**2030**	**2020**	**2030**
Heating and Cooling	61.4	57.8	55.3	57.4	54.4
- Electricity	6.5	6.5	6.6	8.3	13.4
Other Heat uses	23.9	21.6	21.2	21.8	22.0
- Electricity	7.0	6.3	6.2	6.6	7.4
Specific Electricity	14.7	20.6	23.5	20.8	23.6
Total Electricity	28.1	33.4	36.3	35.7	44.3
- of which specific	14.7	20.6	23.5	20.8	23.6
- of which substitutable	13.4	12.8	12.8	14.9	20.7

	Baseline Scenario			Role of Electricity	
Consumption	**2005**	**2020**	**2030**	**2020**	**2030**
Total Energy (Mtoe)	468	552	579	509	524
Electricity (TWh)	1532	2147	2444	2114	2701
Efficiency (% change from 2000)	**2005**	**2020**	**2030**	**2020**	**2030**
Total Energy	2.5	17.9	27.6	21.8	36.0
Heating and Cooling	1.3	18.4	33.8	22.9	44.9
Specific electricity	8.0	17.9	20.5	22.8	30.2

The domestic sector (residential and tertiary taken together) undergoes considerable change with respect to energy efficiency. To this end, the contribution of new electro-technologies is considerable.

In the Baseline Scenario, electricity in the domestic sector increases its share to 36% in 2030 from a share of 28% in 2005. This is driven by widespread inclination to specific electrical uses. Electricity use is higher in "Role of Electricity" driven by the increasing use of electricity in thermal uses, in which electricity attains a share of 20.7% by 2030 up from 12.8% in the Baseline Scenario.

The emission restrictions imposed in the “Role of Electricity” Scenario incite the domestic sector to reduce energy consumption. The reduction is 8% down from Baseline in 2020, 9.5% in 2030 and 5% in 2050. The drop is smaller than in “Efficiency & RES” Scenario which is in line with the fact that the latter scenario focusses mainly on the demand-side of energy to reduce emissions.

In the “Role of Electricity”, the penetration of electro-technologies combined with the cost-effectiveness in reducing emissions at the energy supply sectors allow electricity to penetrate the market of heating and cooling of buildings.

As a result, the sector’s energy efficiency improves and also significant electricity savings take place in specific electrical uses. The saving of energy combined with moderate electricity prices allows households to dispose higher income than in the “Efficiency & RES” scenario. This in turn allows households to use more energy and electricity in order to maximize their welfare. In other words a “rebound” effect takes place in the “Role of Electricity” Scenario: it explains why the reduction of energy consumption in the “Role of Electricity” from the Baseline is significantly lower than the reduction resulted from the comparison of the “Efficiency & RES” Scenario to the Baseline. This difference has no adverse effect on emissions, or on emission abatement costs, since, as it will be shown below, the “Role of Electricity” is more cost-effective than “Efficiency & RES”.

The cost-effectiveness performance is partly due to electro-technologies, which in the domestic sector enable ample electricity substitution for fossil fuels: the share of electricity grows 8 percentage points up from Baseline. At the same time, the energy efficiency of heating and cooling increases by 10 percentage points compared to the Baseline. A similar improvement is observed in specific electrical uses in terms of efficiency of electricity use.

Part of this progress is due to advanced heat pumps. The “Role of Electricity” Scenario projects a substantial market penetration of heat pumps which are projected to cover more than 20% of heating and cooling energy in 2030.

Technological advancement of all kinds of electrical appliances plays an important role in this scenario and justifies its performance with respect to cost of emission reduction. Due to technological progress 9.5% of electricity in electrical uses is saved compared to Baseline; these savings complement electricity penetrating the thermal uses and replacing fossil fuels.

The importance of these changes for cost-effectiveness of emission reduction can be shown by comparing “Role of Electricity” to “Supply Scenario”. In the latter scenario, the lack of improvement of efficiency in electrical uses implies that the supply sector of electricity has to undertake considerably more emission abatement than in the former. In the context of the “Supply Scenario, this difference induces higher marginal costs incurring in power generation.

It is known that the restructuring of the transportation sector towards low carbon intensity is difficult and slow. Besides the dependence on infrastructure, this is explained by the lack of a low carbon energy carrier that can replace petroleum products. Hydrogen, produced by non fossil energy sources, may become such an alternative energy carrier for transportation. Hydrogen distribution for transportation requires a new and capital intensive infrastructure. In addition, carbon free production of hydrogen at a large scale is far from reaching technical and economic maturity. The prospective studies[7] show that hydrogen success in the transport sector, in addition to the development of infrastructure, requires economic maturity of the fuel cells technology, which has improved over the last decades but its cost is still forbidding. For these reasons, the projections claim that more than three decades will be needed before hydrogen vehicles massively penetrate the transport sector.

In the meantime, electricity may constitute, under certain conditions, an attractive alternative energy carrier for transportation. Prerequisites are the possibility to produce electricity with sufficiently low carbon intensity and to develop an affordable motor engine that efficiently uses electricity. The engineering analysis carried out in another section of the present study has shown that there exist positive prospects for developing such a vehicle through the plug-in hybrid technology. The data supporting this prospect have been introduced into the models and have been used only for the “Role of Electricity” Scenario.

The timing of market penetration of plug-in hybrid vehicles (cars, trucks and buses) depends on the gradient of economic and technological improvement of the vehicles and also on the velocity of changes in power generation towards low carbon intensity. The model estimates the degree of market penetration as the outcome of market equilibrium which is driven by the individual economic optimization by consumers (e.g. car owners) and by energy suppliers. The analysis is not limited in the transport sector but involves all interrelated energy markets including the electricity market.

Regarding the transport sector, the model-based analysis illustrates the following mechanisms:

[7] See for example the recent reports by the Cascade-Mints project of DG RES.

- The plug-in hybrid vehicles enable energy efficiency improvement - lower energy consumption per km travelled - as well as electricity substitution for fossil fuels.

- Since CO2 emission restrictions apply, electricity competes against other low carbon intensive solutions for transportation, notably against bio-fuels and fuel cells powered by carbon-free hydrogen.

- The bio-fuels, including bio-diesel and ethanol, entail high costs compared to oil products and involve increasing marginal costs of biomass supply. Therefore electricity not only substitutes for fossil fuels but partly also for bio-fuels, especially within the market for new cars.

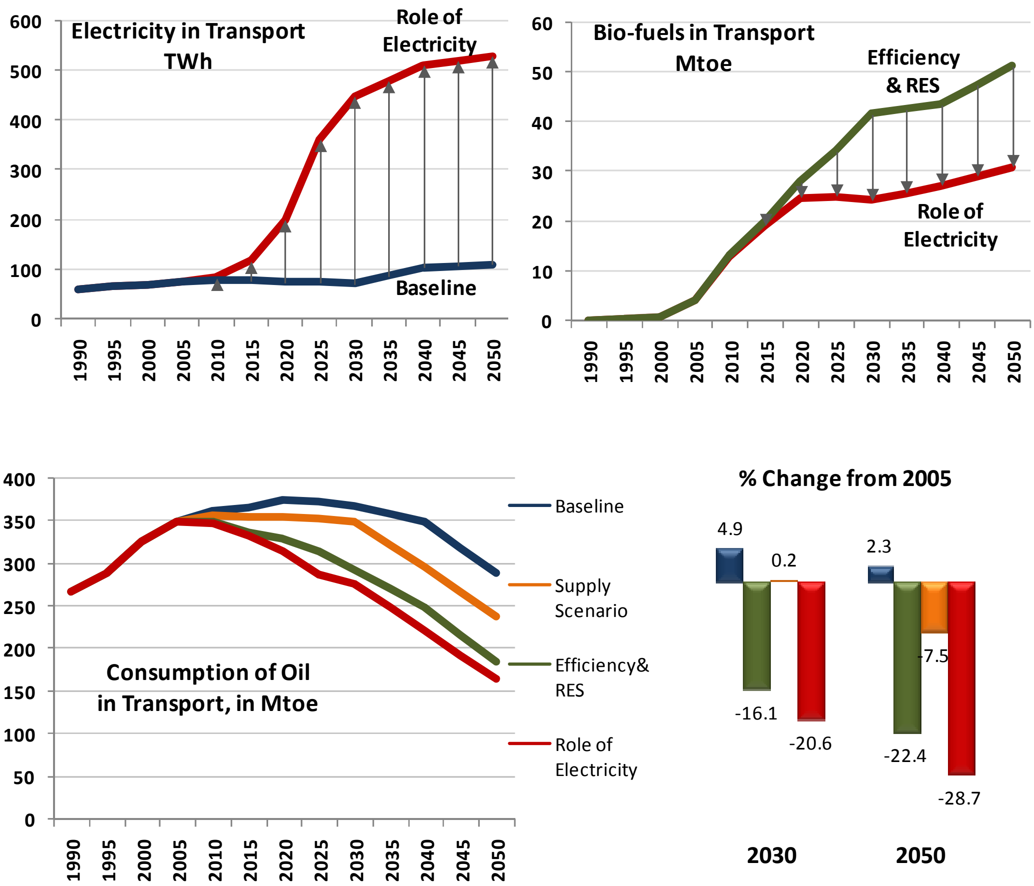
- To penetrate the market, the fuel cells require the development of hydrogen distribution infrastructure, which is unlikely to develop if the market for new cars is already dominated by the plug-in hybrid technology. Transition to fuel-cells is therefore delayed and left for the longer term when emission restrictions are assumed to be more stringent.

Table 5: "Role of Electricity" Scenario EU25 - Energy for transportation (Mtoe)

	Baseline Scenario			% structure				
Transport	**2005**	**2030**	**2050**	**2005**	**2030**	**2050**		
Oil	349	366	289	96.9	91.1	85.4		
Bio-fuels	4	27	36	1.1	6.8	10.6		
Electricity	6	6	9	1.8	1.5	2.8		
Other	1	2	4	0.2	0.6	1.1		
Total	361	402	339					
Efficiency (2005=100)		79.2	59.2					
	Role of Electricity			% structure			% from Baseline	
Transport	**2005**	**2030**	**2050**	**2005**	**2030**	**2050**	**2030**	**2050**
Oil	349	277	166	96.9	81.1	67.8	-24	-43
Bio-fuels	4	24	31	1.1	7.1	12.7	-11	-14
Electricity	6	39	46	1.8	11.3	18.7	527	381
Other	1	2	2	0.2	0.5	0.8	-31	-47
Total	361	342	244				-15	-28
Efficiency (2005=100)		67.4	42.7				-15	-28
	Efficiency & RES			% structure			% from Baseline	
Transport	**2005**	**2030**	**2050**	**2005**	**2030**	**2050**	**2030**	**2050**
Oil	349	293	185	96.9	85.7	75.9	-20	-36
Bio-fuels	4	42	51	1.1	12.1	21.0	53	42
Electricity	6	6	6	1.8	1.8	2.5	-2	-36
Other	1	2	5	0.2	0.5	1.9	-20	24
Total	361	343	248				-15	-27
Efficiency (2005=100)		67.5	43.3				-15	-27

As expected, all alternative scenarios lead to improved energy efficiency of transportation, relative to the Baseline. The "Role of Electricity" and "Efficiency and RES" scenarios are equally efficient in this respect, despite the fact that the latter focuses primarily on demand-side measures to curb emissions.

Figure 44: Comparison of scenarios for transport sector of EU25



Compared to 2005, the Baseline shows considerable improvement of energy efficiency in transportation. The projection also shows dominance of oil products which are blended with bio-fuels, the latter getting a share just above 10% in 2050. Other energy carriers do not develop under the conditions of the Baseline Scenario.

The plug-in hybrid vehicles drive electricity reaching a market share of 11.3% in 2030 and 18.7% in 2050 and energy efficiency improvement which is 15% up from Baseline in 2030 and 28% in 2050. Consumption of oil products is substantially reduced from Baseline: 24% lower in 2030 and 43% lower in 2050. This is a remarkable reversal of transport dependence on oil products. Consumption of oil products is halved in 2050 compared to 2005. Consumption of bio-fuels is maintained at their level in Baseline. Other energy carriers do not penetrate the market.

Regarding bio-fuels, the results of “Role of Electricity” are in contrast with those of “Efficiency & RES”: the latter shows substantially higher use of bio-fuels up to 21% of total energy for transportation in 2050. “Efficiency & RES" also curbs dependence on oil products but it does not use electricity as a new carrier for transportation.

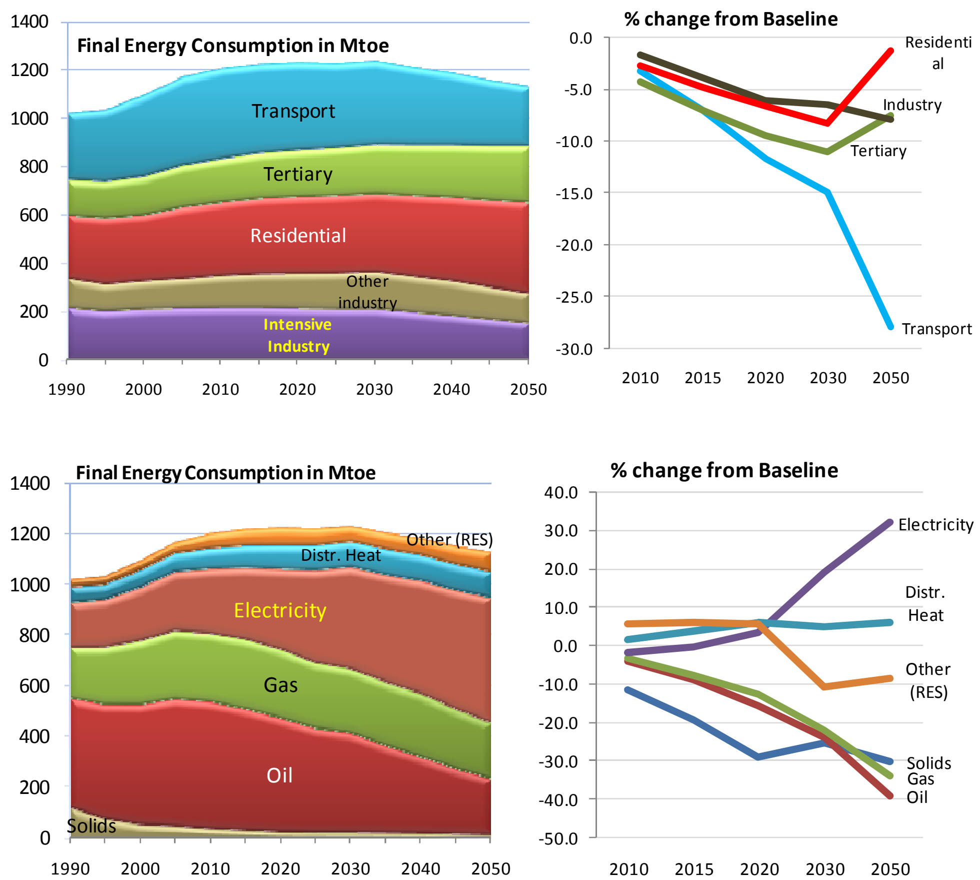
The changes in the transport sector, both in terms of efficiency and substitution for oil, play a considerable role in this scenario and partly explain its cost-effectiveness.

The new market for electricity created through transportation represents 10% of total electricity consumption during the period from 2025 to 2050.

Electricity use is higher than Baseline in all demand sectors. Total demand for electricity is 20% (750 TWh) up from Baseline in 2030 and 32% (1400 TWh) in 2050. The average rate of growth of electricity demand in the period 2005 to 2030, from 1.5% per year in Baseline grows to 2.2% per year in "Role of Electricity" Scenario.

8.3. Final Energy Demand

Figure 45: "Role of Electricity" Scenario EU25 – Final Energy Demand



The "Role of Electricity" Scenario describes an evolution of final energy consumption marked by increasing energy efficiency and by higher use of electricity which substitutes for fossil fuels.

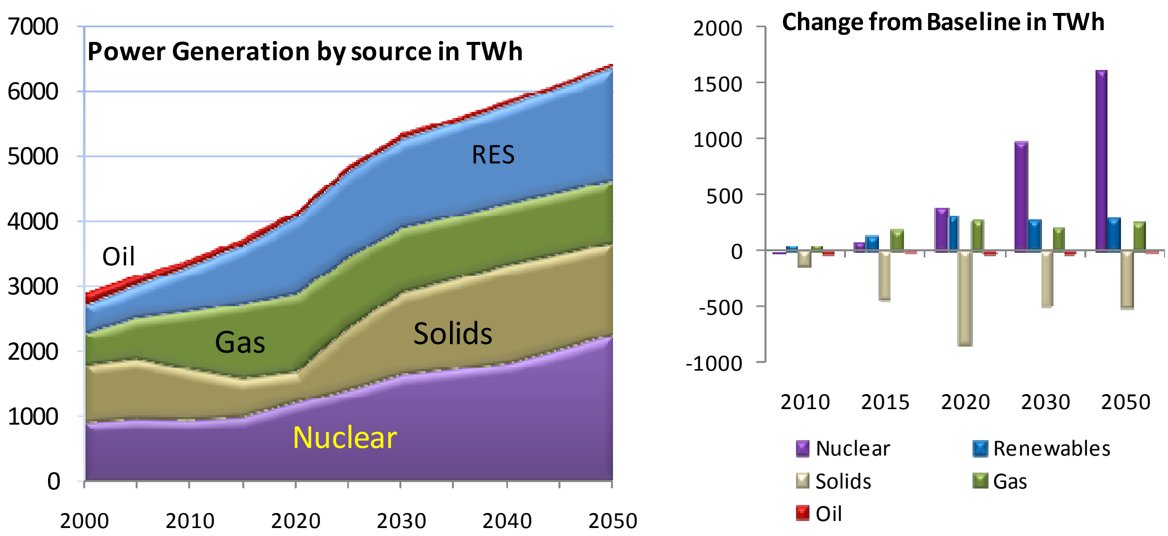
Compared to the Baseline, final energy demand is lower in all sectors and especially in the transport sector. Energy use reduction in this sector is far larger than in the alternative scenarios. Energy consumption in other sectors is however higher than in the "Efficiency & RES" Scenario. This is a result of a "rebound" effect since the cost of energy is perceived to be lower than under the conditions of "Efficiency & RES".

8.4. Power Sector

Power generation faces a considerable increase in demand for electricity, as compared to Baseline. To curb CO_2 emissions, power generation considers as available all means, including further development of nuclear without policy restrictions, CCS and renewables. Therefore, it is possible to shift away from carbon intensiveness and thus support extensive use of electricity in final demand sectors.

The results of the models show that all carbon reduction means are used at least as much as in the "Supply Scenario".

Figure 46: "Role of Electricity" Scenario EU25 - Power Generation by Source



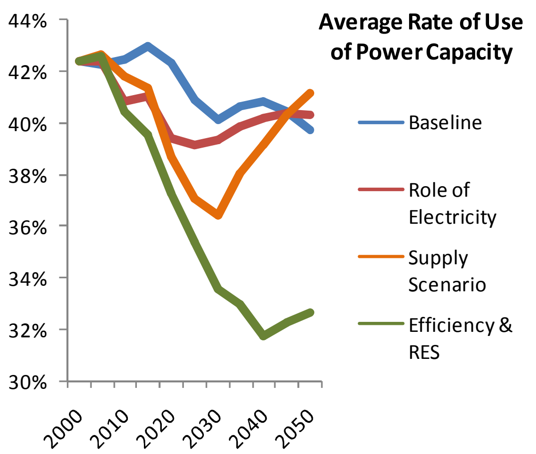
Total power generation is higher than in all other scenarios. The structure of generation undergoes considerable change: a) all carbon free sources develop close to their potential; b) generation from coal reduces in the medium term and is replaced by generation from gas; c) generation from coal re-emerges in the long term facilitated by the widespread application of the CCS technology; d) however generation from gas does not vanish, on the contrary it remains at a higher level from baseline.

Coal consumption for power generation is around 100 Mtoe (30% lower) down from Baseline, despite the development of CCS. On the contrary, gas consumption in the power sector is 35 Mtoe (25% higher) up from

Baseline. Gas consumption stabilises at 150 Mtoe in the long term, which is similar to gas use in the "Efficiency & RES", but much higher than gas use in the "Supply Scenario".

As a consequence of high growth of electricity demand, the "Role of Electricity" Scenario implies higher power generation investment than any other scenario. Total investment over the study period, 2000-2050, is 29% higher from Baseline (446 GW more plants). This means that the "Role of Electricity" Scenario involves, for the period 2000 to 2050, power investment of 40 GW on average per year, instead of 31 GW in the Baseline, 36 GW in the "Efficiency & RES" and 32 GW in the "Supply Scenario".

Figure 47: Relative Use of Power Generation Capacities



All alternative scenarios invest partly to replace old plants faster than in Baseline. The scenarios that involve a high share of RES-power invest more than others in terms of installed capacity because renewables are intermittent sources and the average use of RES-power is small. The "Role of Electricity" presents a relatively high rate of use of power capacities[8] because tricity demand grows more than in other scenarios.

The decomposition of power generation investment by energy source shows for all cases that the "Role of Electricity" involves higher investment than any other scenario, except for RES-power compared to the "Efficiency & RES". Even investment in nuclear and coal with CCS is found higher in "Role of Electricity" than in the "Supply Scenario".

Nuclear investment mainly takes place beyond 2030 because the extension of lifetime of old plants and the abolishment of nuclear phase-out in three countries allows maintaining sufficient nuclear capacity before 2030.

Nuclear investment in the "Role of Electricity" before 2030 is equal to 104 GW instead of 50 GW in Baseline.

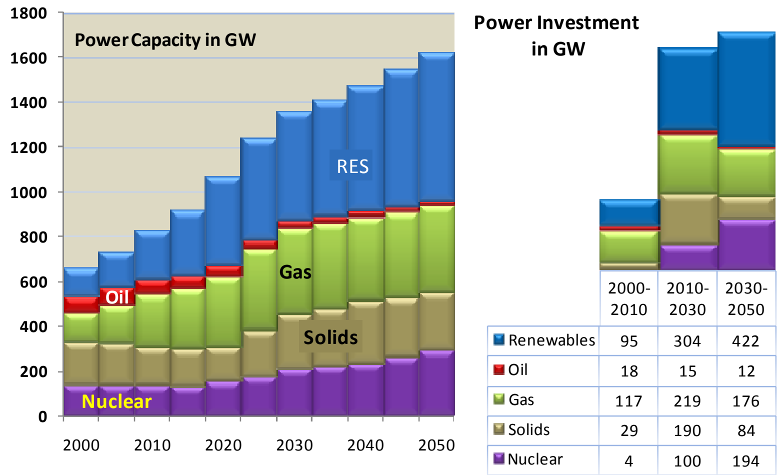
[8] This rate is calculated by dividing electricity consumed in final demand sectors by total gross electricity that could have been generated if nominal capacities were used at 100%.

Table 6: "Role of Electricity" Scenario EU25 – Differences in Power Generation Investment

% Change from	Total	Nuclear	RES	Solids	Gas	Oil
Baseline	29	245	27	-16	28	13
Efficiency & RES	11	163	-23	197	10	17
Supply Scenario	23	8	17	20	48	19
GW Diff. from	**Total**	**Nuclear**	**RES**	**Solids**	**Gas**	**Oil**
Baseline	446	212	177	-60	113	5
Efficiency & RES	198	185	-243	201	48	7
Supply Scenario	369	23	122	51	166	7

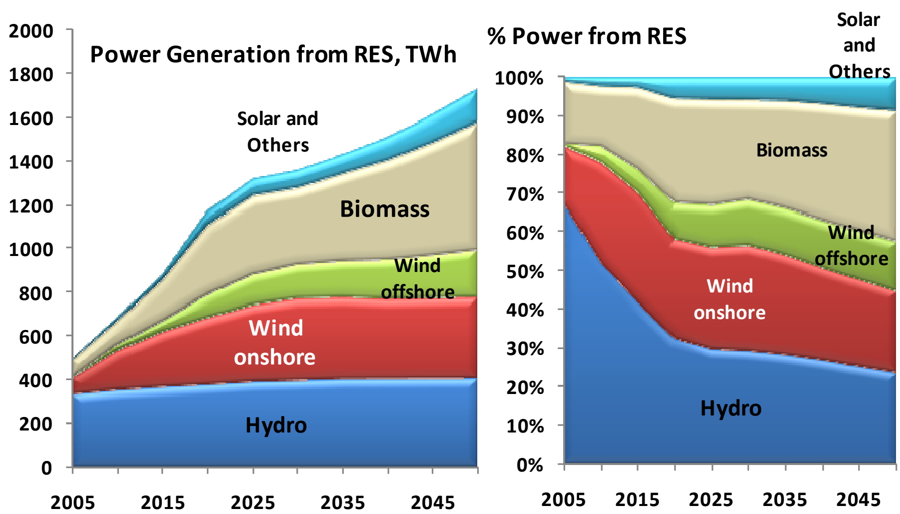
Investment in CCS power plants is significant - of the order of 225 GW- and is 15% lower than in the "Supply Scenario". Two third of the new CCS plants are built in the period 2025 to 2035. The large majority of CCS plants are burning coal or lignite.

Figure 48: "Role of Electricity" Scenario EU25 - Power Capacities



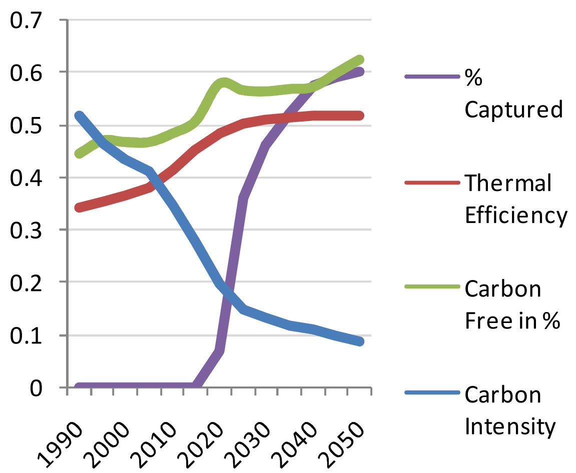
	2000-2010	2010-2030	2030-2050
Renewables	95	304	422
Oil	18	15	12
Gas	117	219	176
Solids	29	190	84
Nuclear	4	100	194

Figure 49: "Role of Electricity" Scenario EU25 - Renewables in Power



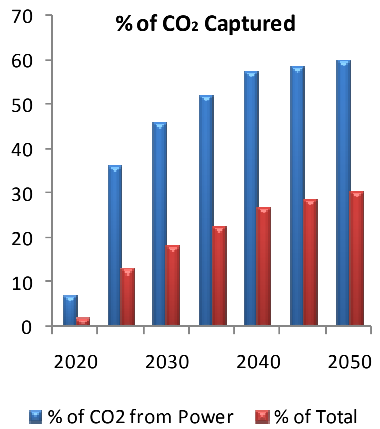
Investment in RES-power is higher in the "Role of Electricity" than in the "Supply Scenario" (by 17%) and the Baseline (27%) but lower by 23% than the "Efficiency & RES" during the period 2000 to 2050. All renewable energy forms develop fast in the "Role of Electricity", except biomass when compared to "Efficiency & RES". Nevertheless, biomass-fired power generation also plays an important role in the "Role of Electricity" Scenario. Solar energy develops fast beyond 2030 when wind power development slows.

Figure 50: "Role of Electricity" Scenario EU25 - Carbon Indicators



As a consequence of extensive restructuring, the power sector achieves very low carbon intensity, which from 0.41 tCO_2/MWh in 2005 goes down to 0.13 in 2030 and 0.08 in 2050. This is not as low as in the "Supply Scenario" but significantly lower than in the "Efficiency & RES" Scenario. This achievement is important because the "Role of Electricity" scenario involves a much bigger electricity sector than the other scenarios and is a combined effect from the growing contribution of nuclear, CCS and renewables.

Figure 51: "Role of Electricity" Scenario EU25 - Capture of CO2 Emissions



Capture of CO_2 is lower, in percentage terms, than in the "Supply Scenario" but 30% higher in volume terms. The loss of thermal efficiency due to CCS is negligible relatively to the overall efficiency and carbon intensity improvements. Carbon free power generation (nuclear and RES) represents 60% of total generation and is, in volume terms, 10% higher than in "Supply Scenario". By 2050, CCS captures 30% of total CO_2 emitted by the entire energy system; this is slightly higher than in the "Supply Scenario".

8.5. Primary Energy Demand and Supply

As mentioned, the "Role of Electricity" Scenario involves electricity substitution for fossil fuels in final energy demand sectors at a considerable degree and extensive use of carbon free energy sources, as well as coal-based CCS, in power generation.

The combined changes in demand and supply of energy induce considerable decrease of total primary needs for oil and for gas. This is a remarkable positive ancillary benefit from the policies underlying the “Role of Electricity” Scenario.

The demand for oil is reduced mainly because electricity substitutes for oil in the transport sector and also because in all sectors energy efficiency improves. Total primary energy needs for oil drops in 2050 down to 45% of total needs in 2005. Demand for oil decreases throughout the projection period and already in 2030 is 22% lower than in 2005. Dependence on oil from 37% in 2005 goes down to 16% in 2050. This performance, which is far better than in the other alternative scenarios, is of course a result of successfully introducing an alternative energy carrier in the transportation sector.

Table 7: "Role of Electricity" Scenario EU25 - Primary energy demand for gas

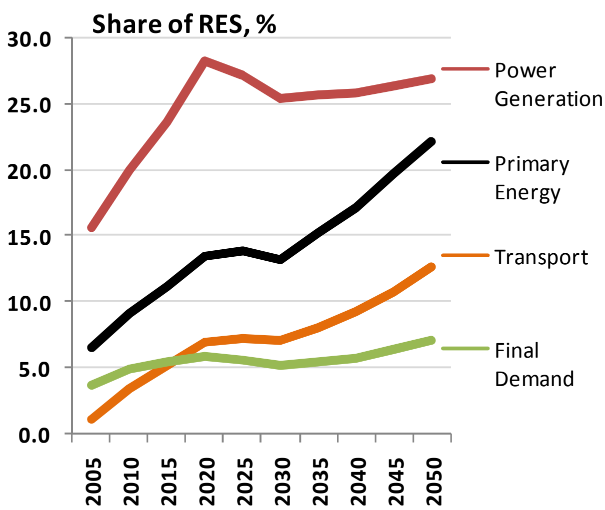
	Role Electricity			Diff. from Baseline		
Mtoe	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**
Total	**497**	**446**	**400**	**-9**	**-54**	**-91**
Power Sector	196	158	147	42	32	37
Other Sectors	30	35	35	-11	-13	-15
Final Demand	272	253	218	-40	-73	-113
	Diff. from Efficiency&RES			**Diff. from Supply Scenario**		
Mtoe	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**
Total	**-13**	**-34**	**-34**	**-28**	**-23**	**-21**
Power Sector	-4	1	-6	4	47	87
Other Sectors	-3	-9	-9	-9	-14	-16
Final Demand	-7	-26	-19	-23	-55	-92

The decomposition by sector of consumption of natural gas undergoes significant change in the context of the “Role of Electricity” Scenario. In Baseline scenario approximately 65% of gas is used in final demand and 35% in power generation. In “Role of Electricity” Scenario, this structure becomes 55% for gas in final demand and 45% for power generation. The reduction of gas consumption in final energy demand is the result of energy efficiency improvement and of the increased use of electricity. Although consumption of gas for power generation increases in “Role of Electricity” compared to Baseline and to all other scenarios, total primary energy demand for gas is found substantially lower than in any other scenario.

Therefore, despite the stringent CO_2 emission targets, the “Role of Electricity” succeeds to reduce dependence on gas; in this respect the scenario delivers another ancillary benefit. This is also a remarkable result stemming from the combined changes in demand and in supply of energy. Total gas needs are found lower even from the “Supply Scenario” which involves considerable reduction of gas used in power generation but fails to reduce final demand for gas.

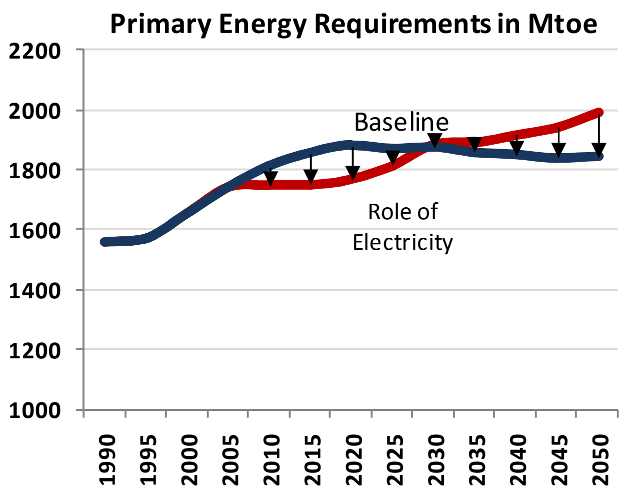
The contribution of renewables in the "Role of Electricity" Scenario is also remarkable. The share of RES in power generation is above 25% in the period beyond 2020. The share of renewables in total primary energy needs exceeds 20% as approaching 2050. However, the shares of bio-fuels in transportation and of other renewables in final energy demand sectors are lower than in the "Efficiency & RES" Scenario.

Figure 52: "Role of Electricity" Scenario EU25 – Renewables



The renewables mainly develop for power generation and CHP, contrary to the "Efficiency & RES" Scenario in which renewables also develop for final energy. Power and Steam from CHP is significantly higher in "Role of Electricity" than in other scenarios. The CHP applications are developed to a level almost exhausting their potential: 28% of electricity is produced by CHP plants and their total power and steam generation is 20% higher than in the "Efficiency & RES" Scenario.

Figure 53: "Role of Electricity" Scenario EU25 - Total Primary Energy Demand



Despite the considerable decrease of final energy demand enabled by "Role of Electricity" compared to Baseline, primary energy demand is similar to the Baseline, even slightly higher in the long term. This is due to the augmentation of the secondary energy sector, mainly power and steam generation. Despite the high level of primary energy demand, both carbon reduction and lower dependence on gas and oil imports are achieved in the context of the "Role of Electricity" Scenario.

The restructuring of primary energy demand by source is dominated by nuclear and renewables increasingly substituting for fossil fuels, mainly for coal and oil. On average primary energy requirements for solid fuels drop by 30% from baseline. The decline of oil needs is 15% from Baseline in the medium term and rises to 30% in the long term. Gas needs are not significantly lower in the medium term, as compared to Baseline, but in the longer term they are up to 18% lower from Baseline. The contribution of nuclear energy is substantially higher than in Baseline and exceeds even the "Supply Scenario" by 5%. Renewables also register a faster development than in the Baseline (by 30% in the medium term and 19% in the long term) but 25% less than in "Efficiency & RES".

Figure 54: "Role of Electricity Scenario" EU25 - Primary Energy Demand

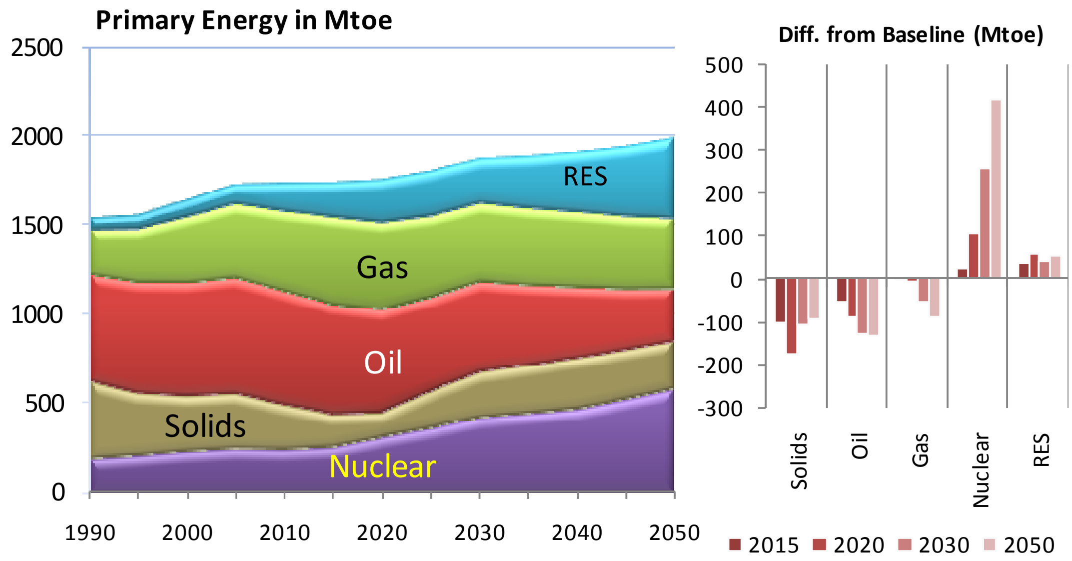
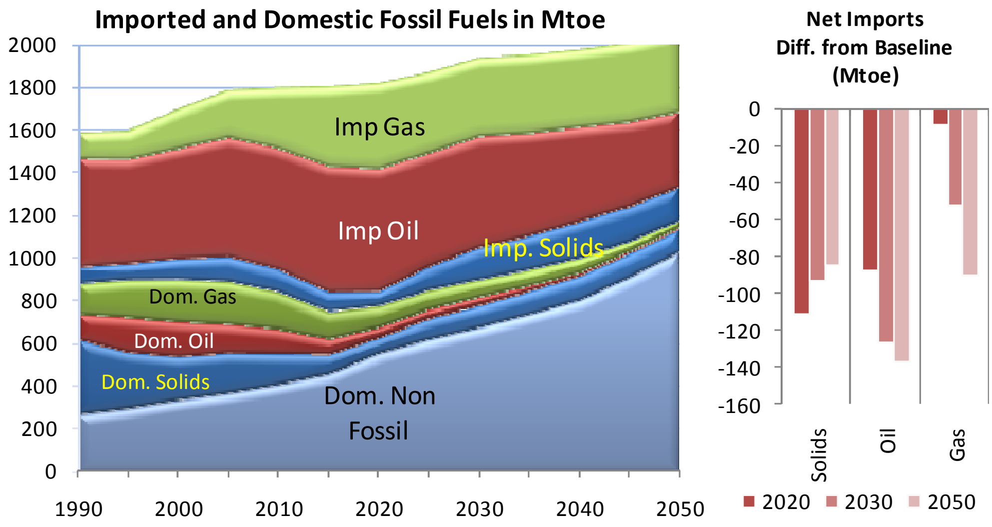


Figure 55: "Role of Electricity Scenario" EU25 - Primary Energy Supply

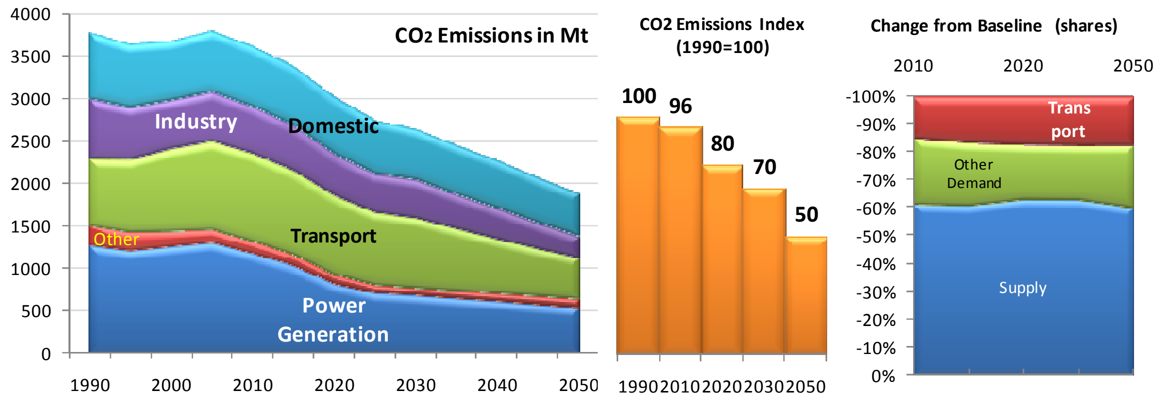


Consequently net imports of oil return by 2030 to their 2000 levels, and further decrease in the longer term reaching in 2050 a levels 28% down from 2005. Net imports of gas remain at their level in Baseline until 2025 and then they decrease (20% down from Baseline in 2050). The volume of net imports of gas stabilises after 2025 to a level 65% higher than in 2005. This is substantially lower than in all other scenarios. Nevertheless, despite the improvement in the context of the "Role of Electricity" Scenario, long-term dependence of Europe on gas imports remains an issue for policy making.

8.6. Impacts on Carbon Emissions

By definition, carbon emissions from energy are reduced in the "Role of Electricity" Scenario as much as in the other alternative scenarios. However, the structure of reduction is different.

Figure 56: "Role of Electricity Scenario" EU25 – CO2 Emissions

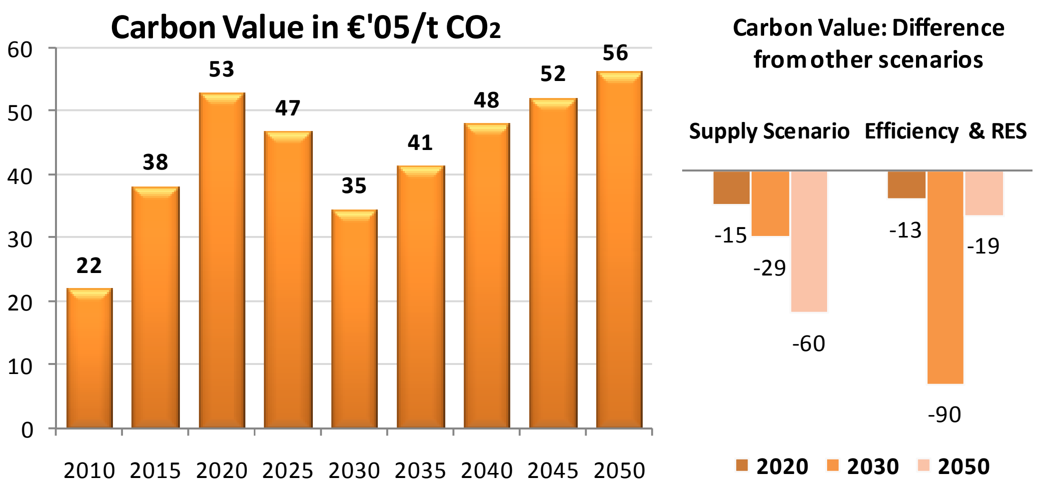


Emission reduction by sector is more balanced than in the other scenarios. The power generation sector plays an important direct role by reducing substantially its carbon intensity, which was also the case in the "Supply Scenario", but electricity now plays an indirect role by substituting for fossil fuels in all final demand sectors, far more than in the other scenarios. On the other hand, the final demand sectors also reduce emissions as a result of improving their energy intensity, similarly to the "Efficiency & RES" Scenario. Consequently, emission reduction in the "Role of Electricity" Scenario is 60% due to power generation and 40% due to final demand sectors. Among them, emission reduction in the transport sector accounts for 15% of total, which is far more important than in any other scenario.

The availability of the new electro-technologies allows electricity to substitute for fossil fuels in final energy demand sectors and improves energy efficiency in demand. It also enables the displacement of expensive carbon abatement (in terms of marginal abatement costs) from demand sector to the energy supply sectors, which succeed to attain a very low level of carbon intensiveness at affordable marginal abatement costs. The latter is due to the balanced emission reduction structure in power generation, since this sector has the possibility of recourse to all kinds of technologies in order to curb CO2 emissions.

The combined effect from changes in demand and in supply sectors, as explained above, leads to significantly lower Carbon Values, compared to the other carbon reducing scenarios. The Carbon Value expresses the marginal difficulty for the system to meet the overall emission reduction target. A lower Carbon Value reveals superior performance of the system and corresponds to a balanced mix of carbon reducing means. Since all means exhibit diminishing returns to scale, a lower Carbon Value signifies that the rate of use of the carbon reducing means is better optimised.

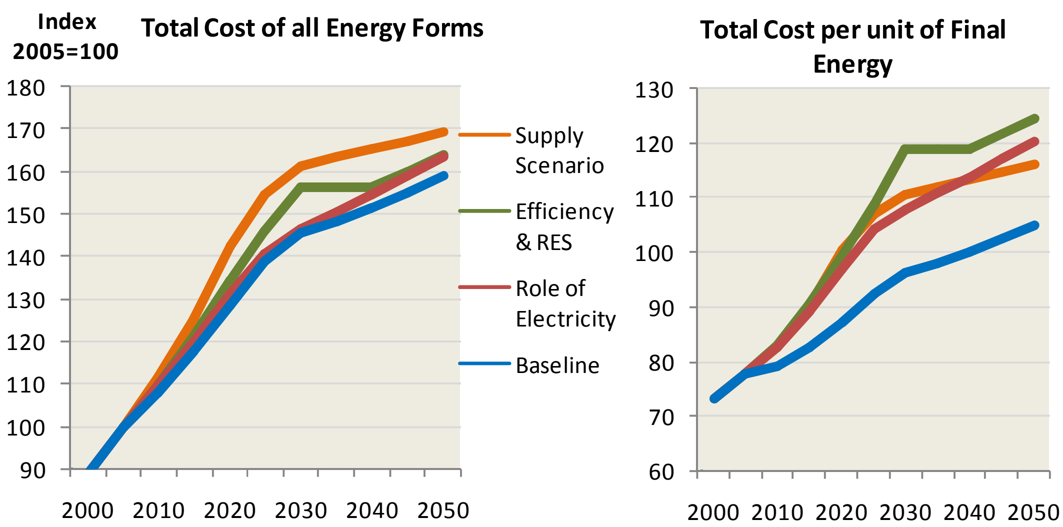
Figure 57: "Role of Electricity Scenario" EU25 – Carbon Value



8.7. Impacts on Costs and Prices

The cost-effective emission reduction in the "Role of Electricity" Scenario, as expressed by the low level of the Carbon Value, allows this scenario to succeed the lowest cost and price rise among all alternative scenarios.

Figure 58: "Role of Electricity Scenario" EU25 – Energy Cost

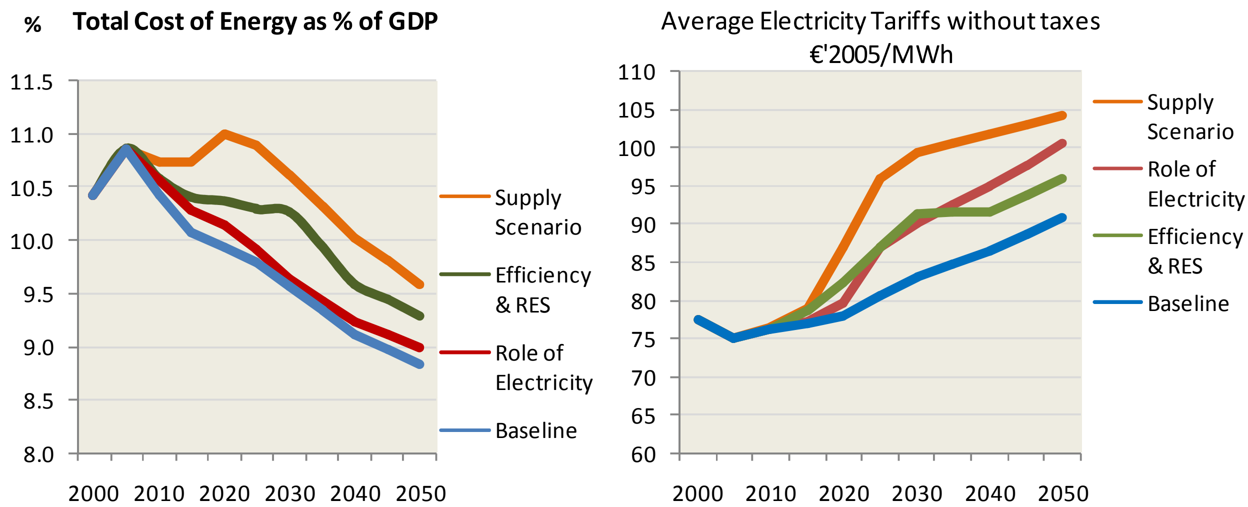


Total energy cost includes the cost of purchasing the fuels as well as the costs incurred for capital investment, purchase of equipment and operation and maintenance in all end-use sectors. This represents all energy-related costs incurred in end-use sectors and depends indirectly on costs incurred in the energy supply sectors.

Total energy cost increases over time as a consequence of growing energy demand and rising world fossil fuel prices in real terms. All alternative scenarios imply higher total energy cost from Baseline. In cumulative terms, for the period 2005 to 2050, the additional cost is 7.5% higher than Baseline in the "Supply Scenario" and 3.6% in the "Efficiency & RES" Scenario. The "Role of Electricity" Scenario has the lowest cost implications for the consumers of energy: 1.6% cumulatively above Baseline levels.

Total cost per unit of delivered final energy also increases from Baseline. The rate of increase in the period 2030 to 2050 is 19% for the "Efficiency & RES" Scenario, 13.5% for the "Supply scenario" and 12.8%% for the "Role of Electricity" Scenario. The "Efficiency & RES" Scenario leads to high unit cost of energy but involves lower total energy consumption than other scenarios.

Figure 59: "Role of Electricity Scenario" EU25 – Electricity Prices and Cost/GDP



As a result of emission reduction, electricity prices also rise from Baseline. On average for the period 2020 to 2050, electricity prices in real terms increase from Baseline by 15.3% in the "Supply Scenario", and by 7% in the "Efficiency & RES" and the "Role of Electricity" Scenarios. The "Role of Electricity" implies slightly higher electricity prices than the "Efficiency & RES" but lower total energy cost for the consumers.

Total energy cost as percentage of GDP increases from Baseline. The lowest increase is obtained for the “Role of Electricity” Scenario and is slightly above Baseline.

This is a remarkable result which underlines the superior performance of the “Role of Electricity” Scenario in terms of cost-effectiveness of carbon reducing policy.

Comparison of Scenarios and Conclusions

9. Summary of Approach

The aim of the modelling work carried out within the Role of Electricity project was to quantify long-term scenarios for the future evolution of the energy demand and supply sectors in Europe. For this purpose, the PRIMES energy system model has been applied to provide detailed projections up to 2030 and the Prometheus world energy model has been applied to perform consistency analysis of world energy markets and longer-term projections up to 2050.

The projections based on the PRIMES model were carried out with a high level of detail, on a country-by-country basis for all current and potential future members of the European Union (in total 30 countries). This report shows only aggregate results for the EU-25.

The Prometheus model has analysed endogenously the formation of world energy prices. It treats Europe as a single region but views it as part of a global, worldwide energy system and market.

The databases of both models have been considerably updated and supplemented with data and information provided by the other two teams working on the supply- and demand-side sections of the study, applying a bottom-up approach. These teams provided technical and economic estimates of the future evolution of technologies related to power generation and consumers' use of electricity.

A scenario is composed of a set of assumptions and the consequent results of those assumptions worked out through the model. The energy system models start by taking as given a future path of economic growth and then focus on energy demand and supply and the interactions between them that influence the formation of energy market prices. The models do not however take account of any feedback effects from energy on overall economic growth.

As is standard practice, the models are first used to quantify a Baseline scenario and then to quantify alternative policy-oriented scenarios. The baseline scenario serves as a reference against which the alternative scenarios are assessed. This procedure aims at evaluating the impacts and the cost-effectiveness of the policies and measures that are reflected in the assumptions for the alternative scenarios.

10. Summary of results for the Baseline Scenario

The Baseline scenario is essentially a least-cost projection of a future energy system, which does not take account of external costs and impacts, such as the effects on the environment or the geopolitical risks affecting energy supply security. However, it does not freeze progress on energy efficiency or the penetration of new technologies or renewables. On the contrary, energy-efficiency policies and also market trends that lead to improvements in energy productivity do continue into the future under Baseline conditions but, contrary to the alternative scenarios shown below, the Baseline only takes account of policies, standards and measures already in place.

The assumptions for economic growth are optimistic: Europe succeeds in growing at an average rate of 2% per year until 2030 but then growth slows in the longer term to approach 1% per year until 2050. The European economy progressively changes its structure as sectors with higher value-added grow more than sectors that are heavily intensive in terms of energy and materials. European demographics are rather stable.

The Baseline scenario reflects an energy pathway influenced by relatively high oil and gas prices. Oil prices are projected to stabilise in the short-medium term at a level slightly lower than the 2005-2006 peak and to start rising again in the long run, reaching 46€'2005/bbl in 2030 and almost 80€'2005/bbl in 2050. Natural gas prices are projected to be tightly linked with oil prices. Coal prices are projected to rise at far lower rates than oil and gas as a result of high coal resources and more favourable geopolitics. This implies that the competitiveness of gas vis-à-vis coal steadily deteriorates: the gas-to-coal price ratio, at 1.5 in the 90s and 2.5 in 2006, approaches 3 before 2030 and then reaches the value of 5 in 2050.

The European Baseline outlook shows total primary energy requirements steadily decoupling from economic growth: energy grows by 0.3% per year as a result of overall energy intensity of GDP declining by 1.7% per year. Final energy demand for traditional fuels, such as solids and residual fuel oil is declining. However, oil products, mainly diesel oil and gasoline, are massively employed in specific uses, mainly for transport. Final demand for natural gas increases by 1.1% per year but slows down in the longer term due to high prices and saturation. Transport remains the fastest-growing energy demand sector explaining persistence of total demand for oil, with oil demand decline starting smoothly in Europe beyond year 2030.

Electrification in energy demand is projected to continue under the Baseline scenario, continuing past trends: electricity demand grows by 1.3% per year and electricity's energy market share rises steadily from 17% in

1990 to reach 25% in 2030. This reflects electricity driving technological progress and comfort improvement. Consequently power generation needs to expand and invest 825 GW of new plants. Nuclear energy declines over time as a result of policy restrictions in some countries, as it has been assumed for the Baseline Scenario. The use of gas, driven by substantial investment in GTCC and CHP, increases in the medium term and peaks by 2020. Coal re-emerges in the long term driven by relative fuel prices and technological development. Until 2030 more than 250 GW of new coal plants will be built according to the Baseline projection.

Given that Baseline assumes the continuation of supportive policies for renewables, investment in RES-power plants is found to increase substantially: wind energy takes the lead followed by biomass-firing plants. Electricity generation from renewables is projected to represent 25% of total power generation in 2030 and 30% in 2050, up from 15.7% in 2005.

Carbon dioxide (CO_2) emissions, despite increasing significantly less than GDP and even less than total energy requirements, remain far higher than emission reduction targets as required to meet Kyoto obligations and climate-friendly post-Kyoto emissions paths. The considerable energy intensity reductions and the significant penetration of renewables projected under Baseline are not enough to curb CO_2 emissions, because: energy demand trends for transport are steady and no substitute to oil really emerges under Baseline; coal-fired power generation re-emerges in the long run; nuclear generation declines and is replaced by coal. The Baseline scenario projects 10.5% higher emissions in the EU-25 in 2030 than in the base year (1990) and 3% higher emissions in 2050.

Indigenous production of all energy forms in Europe, except renewables, is projected to decline considerably over time. This trend combined with rising energy needs for oil and gas leads to a serious aggravation of energy dependence of Europe on imports. An analysis about the possible origins of incremental supplies of gas to Europe also shows high dependence on Russian and Middle East gas sources. Total import dependency reaches 68% in 2030, from 50% in 2005, while oil and gas net imports per unit of primary energy requirements grows to 57% in 2030, from 45% in 2005.

Despite the remarkable energy intensity gains obtained under baseline conditions, the energy future of Europe under current trends and policies is not sustainable in the long run with respect to environmental impacts. In addition, the persisting high oil needs for transport, the persistently high demand for gas in power supply and in final demand and the declining indigenous energy production in Europe lead to unprecedented long-term import dependency involving high geopolitical risks.

11. Definition of Alternative Scenarios

The alternative scenarios reflect additional policies and measures, especially with respect to the implications of energy import dependence and on climate change.

The analysis of the Baseline results clearly demonstrated that CO2 reduction policies are very closely linked to the two other drivers, import dependency and economic competitiveness. With this in mind, it has been decided to impose on all alternative scenarios, exactly the same target for mitigating carbon dioxide emissions: the EU-25 is constrained to meet an overall CO2 emissions cap of -30% in 2030 and -20% in 2020, compared to 1990. For longer-term analysis, this cap is assumed to become more restrictive: -40% in 2040 and -50% in 2050. This makes the alternative scenarios comparable with each other.

The alternative scenarios, as well as a series of other sensitivity analysis scenarios that have also been carried out, adopt different assumptions in terms of the energy policy approach and the technological developments that are needed to meet the emissions cap. In these terms, the alternative scenarios are defined as follows:

1. The "Efficiency & RES" scenario assumes that policy focusses on energy efficiency and renewables and involves a package of measures promoting energy savings and highly efficient appliances, plus policies facilitating further deployment of renewables, including support for biomass. This scenario does not involve any revision of nuclear policy as compared with baseline and excludes the development of carbon capture and storage (CCS) technology.
2. The "Supply Scenario" assumes that policy focusses mainly on power generation in order to obtain a low carbon energy system and meet the emissions cap. The scenario does not foresee any additional efforts to promote energy efficiency or renewables over and above the Baseline scenario. It also assumes that a new nuclear policy is adopted and put in place, and that CCS is facilitated and successfully developed.
3. The "Role of Electricity" scenario does not exclude any means or options towards a low carbon energy system in Europe. It involves policies promoting energy efficiency on the demand side and policies supportive to renewables as envisaged in the Baseline scenario, but without incorporating any additional policies for renewables or biomass. In addition, this scenario assumes that new demand-side electro-technologies will successfully develop. Some

of these technologies improve energy efficiency in specific electrical uses, such as efficient lighting and motor drives, while others facilitate higher penetration of electricity in substitutable energy uses, including heat pumps and plug-in hybrid vehicles. On the supply side, the “Role of Electricity” scenario mobilises, alongside renewables, both the new nuclear policy and CCS technology, as specified for the Supply scenario.

All alternative scenarios assume that the emissions cap is applied to the EU as a whole and that it will be possible that all sectors and countries of the EU contribute under a perfect allocation scheme to emissions reduction. In other words, all sectors and countries contribute as much as needed to obtain the overall emissions reduction under the condition that all sectors face exactly the same marginal abatement cost. This marginal cost, called “carbon value”, corresponds to the marginal value of the overall emissions cap.

12. Comparison of Alternative Scenarios

All scenarios involve reducing final energy demand. In general, the results confirm that policy must give first priority to energy efficiency in order to reduce the carbon intensity of the European economy.

The results show that “Efficiency & RES” leads to the lowest level of final energy demand compared to other scenarios. Under this scenario, despite economic growth, final energy demand reaches in 2030 almost the same level as in 2005 and then even drops in 2050. This is in line with the main focus of the scenario – improvement in energy efficiency.

Electricity consumption is higher in the “Role of Electricity” scenario because results show that the success of new electro-technologies, leading to higher use of electricity in cars and thermal uses, also enables cost-effective displacement of emissions from the energy demand side to the supply side. This displacement is such that overall emission-abatement costs are reduced and the level of emissions is reduced overall as well. The advanced electro-technologies lead to energy savings in 2030 of up to 10% in the buildings sector and 7% in industry. The share of electricity in total final energy rises in this scenario against Baseline from 25% in 2030, to 32.6% in 2030 and 43.7% in 2050. The share of plug-in hybrid vehicles, within the market of road vehicles, attains 14% in 2030 and 23% by 2050.

Table 8: Final Energy Demand – EU25

	Baseline		Efficiency & RES		Supply Scenario		Role of Electricity	
	2030	2050	2030	2050	2030	2050	2030	2050
Consumption of energy (Index 2005=100)	117.6	109.0	102.1	85.5	113.3	101.1	105.6	96.8
End-use Sectors, except transport	120.3	115.7	105.3	93.0	115.0	109.5	110.4	109.8
Transport Sector	111.5	93.9	95.0	68.7	109.6	82.2	94.9	67.7
Electricity Consumption	144.5	160.3	126.8	138.1	142.8	162.8	172.1	211.5
	05-2030	05-2050	05-2030	05-2050	05-2030	05-2050	05-2030	05-2050
Energy Efficiency (annual average rate, %)	-1.35	-1.46	-1.90	-1.99	-1.50	-1.62	-1.77	-1.72
End-use Sectors, except transport	-1.26	-1.33	-1.78	-1.81	-1.44	-1.45	-1.60	-1.44
Transport Sector	-1.56	-1.78	-2.19	-2.47	-1.63	-2.08	-2.19	-2.50
	2030	2050	2030	2050	2030	2050	2030	2050
Share of Electricity in Final Energy	24.6	29.4	24.8	32.3	25.2	32.2	32.6	43.7
End-use Sectors, except transport	34.1	39.1	34.1	42.2	35.3	42.2	40.8	50.6
Transport Sector	1.5	2.8	1.8	2.5	1.5	2.3	11.3	18.7

Both the “Efficiency & RES” and “Role of Electricity” scenarios show 15% lower energy demand for transport in 2030 than Baseline. This is due equally to a shift in favour of using public transport and to higher efficiency of vehicles.

Both scenarios also improve transport’s performance in terms of carbon intensity, through greater use of bio-fuels in the “Efficiency & RES” scenario (14% in 2030 and 21% in 2050) and greater use of electricity in the “Role of Electricity” scenario (11% in 2030 and 19% in 2050). Hydrogen and fuel cells emerge very slowly and mainly after 2045.

The “Role of Electricity” scenario involves substantial reduction of the demand for fossil fuels by end-use sectors, including end-use of gas and oil, which are found 30% in 2030 and 57% in 2050 down from Baseline.

The “Efficiency & RES” scenario also reduces the end-use of gas and oil (20% in 2030 and 45% in 2050 down from Baseline) but in this scenario this is an outcome of energy efficiency improvement and not of substitution by electricity.

The “Supply Scenario”, focusing on displacing fossil fuels from power generation, involves far less reduction of gas and oil use in end-uses: 5% in 2030 and 15% in 2050 down from Baseline.

Table 9: Nuclear Capacity and Investment – EU25

GW		Baseline		Efficiency & RES		Supply Scenario		Role of Electricity	
	2000	2030	2050	2030	2050	2030	2050	2030	2050
Capacity	141	81	81	106	106	199	269	213	292
		05-2030	30-2050	05-2030	30-2050	05-2030	30-2050	05-2030	30-2050
Decommissioning		111	36	111	38	33	115	33	115
Extension of Lifetime		0	0	0	0	78	0	78	0
New Investment		51	36	76	38	91	184	104	194
Diff. from Baseline				25	2	40	148	54	158

In the two scenarios involving new nuclear policy, namely the "Supply Scenario" and the "Role of Electricity", nuclear power generation is around 60% higher in 2030 compared to 2005; it more than doubles in 2050. The extension of lifetime of old nuclear plants takes place only in these two scenarios and applies to 70% of nuclear capacity that otherwise would have been decommissioned until 2030. The extension of the lifetime of older nuclear plants accounts for 78 GW and, by reducing cost, has a diminishing effect on electricity generation prices. New investment in the period 2030 to 2050 mainly replaces plants to be decommissioned (60% of total investment). The majority of the remaining new plants can be constructed by extending existing nuclear sites.

Table 10: Development of Renewables – EU25

		Baseline		Efficiency & RES		Supply Scenario		Role of Electricity	
	2005	2030	2050	2030	2050	2030	2050	2030	2050
RES (Mtoe)	114	208	391	328	599	255	522	248	441
- as % of Primary Energy	*6.5*	*11.1*	*21.2*	*20.1*	*36.8*	*13.3*	*25.8*	*13.2*	*22.2*
RES-Power (TWh)	499	1092	1437	1675	2097	1267	1558	1359	1729
- as % of Power Generation	*15.7*	*18.1*	*30.1*	*21.7*	*51.0*	*19.0*	*31.7*	*20.1*	*26.9*
RES-Transport (Mtoe)	4	27	36	42	51	37	46	24	31
- as %	*1.1*	*6.8*	*10.6*	*12.1*	*20.7*	*9.4*	*15.5*	*7.1*	*12.7*

In all the alternative (non-Baseline) scenarios, electricity from renewable sources increases substantially from 2005. Particularly in the "Role of Electricity" and "Efficiency & RES" scenarios, RES-electricity expands in a range between 3 and 4 times higher than its level in 2005. In all alternative scenarios, renewables cover 20% of total electricity generated in 2030. Wind power takes the lead of RES development, followed by biomass and solar energy in the long term.

Renewables achieve their highest share under "Efficiency & RES": 45% of total power capacity (in nominal terms) in 2030 and 57% in 2050. In terms of electricity generated, RES produce 51% in 2050. This scenario allows renewables to cover 20% of total primary energy requirements in 2030, but compared to the other two scenarios, the additional contribution of renewables is mainly related to the additional development of biomass.

Bio-fuels make significant inroads into the market in all alternative scenarios, particularly in the context of the "Efficiency & RES". The lowest share is obtained in the "Role of Electricity", as bio-fuels seemingly compete against electricity in the transportation market.

Table 11: CCS capacity – EU25

	Supply Scenario		Role of Electricity	
	2030	**2050**	**2030**	**2050**
Capacity of Plants with CCS (GW)	182	209	143	194
- of which coal	159	183	143	184
- of which gas	23	26	0	9
CCS capacity % of Fossil Fuel plants	*32.1*	*47.6*	*21.6*	*27.6*
	20-2030	**30-2050**	**20-2030**	**30-2050**
CCS Investment (GW)	182	77	143	78
- as % of New Fossil Fuel plants	68	53	41	29
CO2 Captured (Mt CO2 per year)	671	671	587	818
- as % of CO2 from Power Sector	*71.0*	*86.6*	*46.1*	*58.8*

CCS technology allows considerable avoidance of emissions. In the "Supply Scenario", more than 70% of the CO2 emitted from power generation in 2030 is captured and stored, compared with 42% in "Role of Electricity". Under both the "Supply Scenario" and the "Role of Electricity" about 5 billion tons of CO2 are stored underground from 2020 to 2030 and 14 billion additional tons from 2030 to 2050. This may be compared against a total CO2 storage potential of more than 70 billion tons of CO2. The total market for new CCS power plants is estimated 250 GW and their commissioning mainly take place between 2025 and 2040.

Table 12: Power Generation Investment - EU25

GW		Total	Nuclear	RES	Solids	Gas	Oil
Baseline	00-30	928	51	297	281	261	38
	30-50	605	36	347	82	138	1
Efficiency & RES	00-30	984	76	520	67	292	29
	30-50	797	38	543	35	171	10
Supply Scenario	00-30	950	91	368	179	285	27
	30-50	659	184	330	73	61	11
Role of Electricity	00-30	1090	104	398	219	336	33
	30-50	888	194	422	84	176	12

Power generation investments work out higher than Baseline in all alternative scenarios. This is related to premature scrapping of some of the older plants but also to RES since the RES have a low average rate of use. All sectors and mainly power generation are challenged to undertake substantial investment that must be based on advanced technologies in order to comply with the emission restrictions.

In the "Role of Electricity" and the "Supply Scenario" total cost of capital in energy supply sectors is projected to rise 25% up from Baseline in cumulative terms for the period 2005 to 2030. Capital cost increases in "Efficiency & RES" are lower because of the lower demand for electricity.

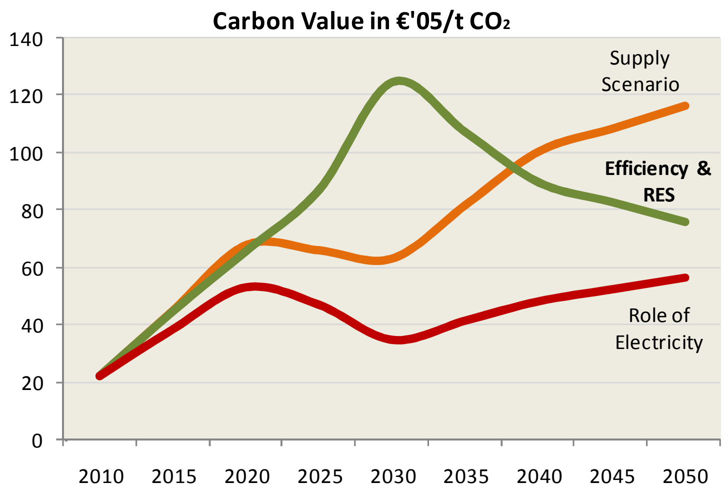
Additional costs are incurred from the restructuring of the end-use sectors. The lowest increase in total energy cost in demand sectors – at 1.7% from Baseline in cumulative terms – incurs in the "Role of Electricity", and the highest in the "Supply Scenario" (8.8%).

Table 13: Impacts on Cost of Energy – EU25

billion €'05	Baseline	Efficiency & RES	Supply Scenario	Role of Electricity
Cumulative Capital Cost (2000-2030)	21,087	20,914	21,396	21,566
- demand	16,315	16,065	16,116	16,272
- supply	4,772	4,850	5,281	5,294
Cumulative Fuel Cost (2000-2030)	28,568	30,329	31,472	29,327
Cumul. Total Energy Cost (2000-2030)	49,655	51,243	52,869	50,893
Change from Baseline in %				
Capital Cost		-0.8	1.5	2.3
Fuel Cost		6.2	10.2	2.7
Total Energy Cost		3.2	6.5	2.5
Cost of Energy as % of GDP in 2030	9.57	10.27	10.61	9.64
Add. Cost 2005-2030 (billion €)		1,588	3,214	1,238
Avg Cost of CO2 Abated (€/tCO2) '05-50		63	133	50
Marginal Cost of CO2 in 2030 (€/tCO2)	5	125	63	35
Marginal Cost of CO2 in 2050 (€/tCO2)	5	76	116	56

The considerable restructuring of power generation is accompanied by higher average electricity prices, 20% higher in the "Supply Scenario", 10% higher in the "Efficiency & RES" Scenario and the lowest increase of 8.3% under the "Role of Electricity" Scenario.

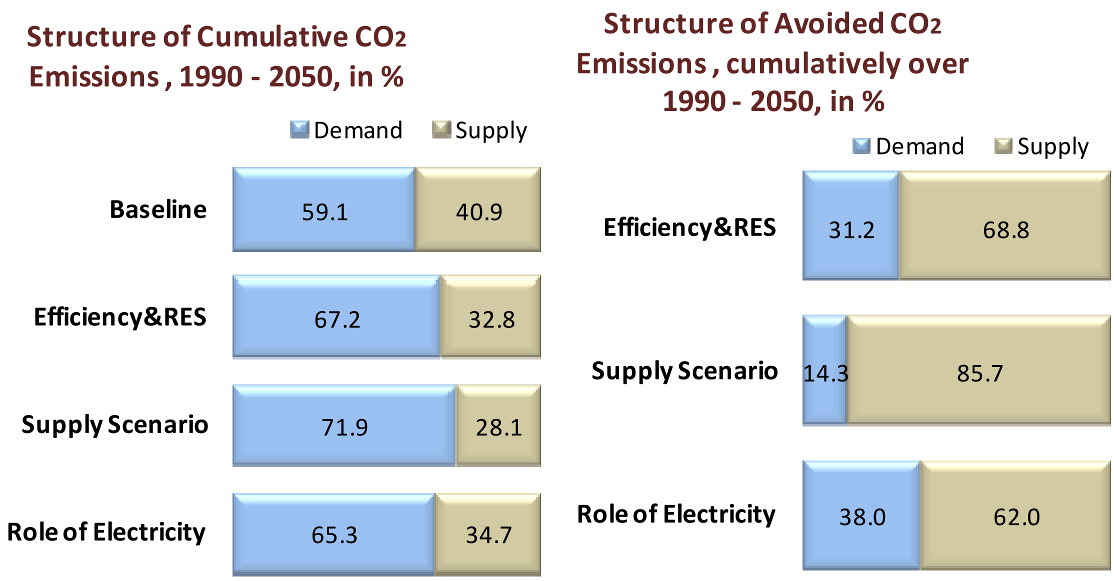
Figure 60: Marginal Costs of Emission Reduction (Carbon Value) – EU25



With respect to all cost and price indicators, the "Role of Electricity" performs better than the other two scenarios. Both the average cost and the marginal cost of CO2 emission abatement are lower in the "Role of Electricity" than in the other scenarios. This performance is due to the combinations of the balanced portfolio of carbon reducing means and the penetration of the new electro-technologies.

All three alternative scenarios transform power generation into a very low-carbon-intensive energy conversion sector: from 0.43t of CO2 per MWh in 2000, the emissions from the European power sector decline in 2030 to 0.15 tCO2/MWh under Efficiency & RES, to 0.13 tCO2/MWh under Role of Electricity and to as low as 0.06 tCO2/MWh under the Supply scenario. Carbon intensity of power generation declines even more in 2050 and becomes equal to 0.12, 0.08 and 0.02 tCO2/MWh, in the respective scenarios. The carbon intensity of power generation in the Baseline remains above 0.33 tCO2/MWh.

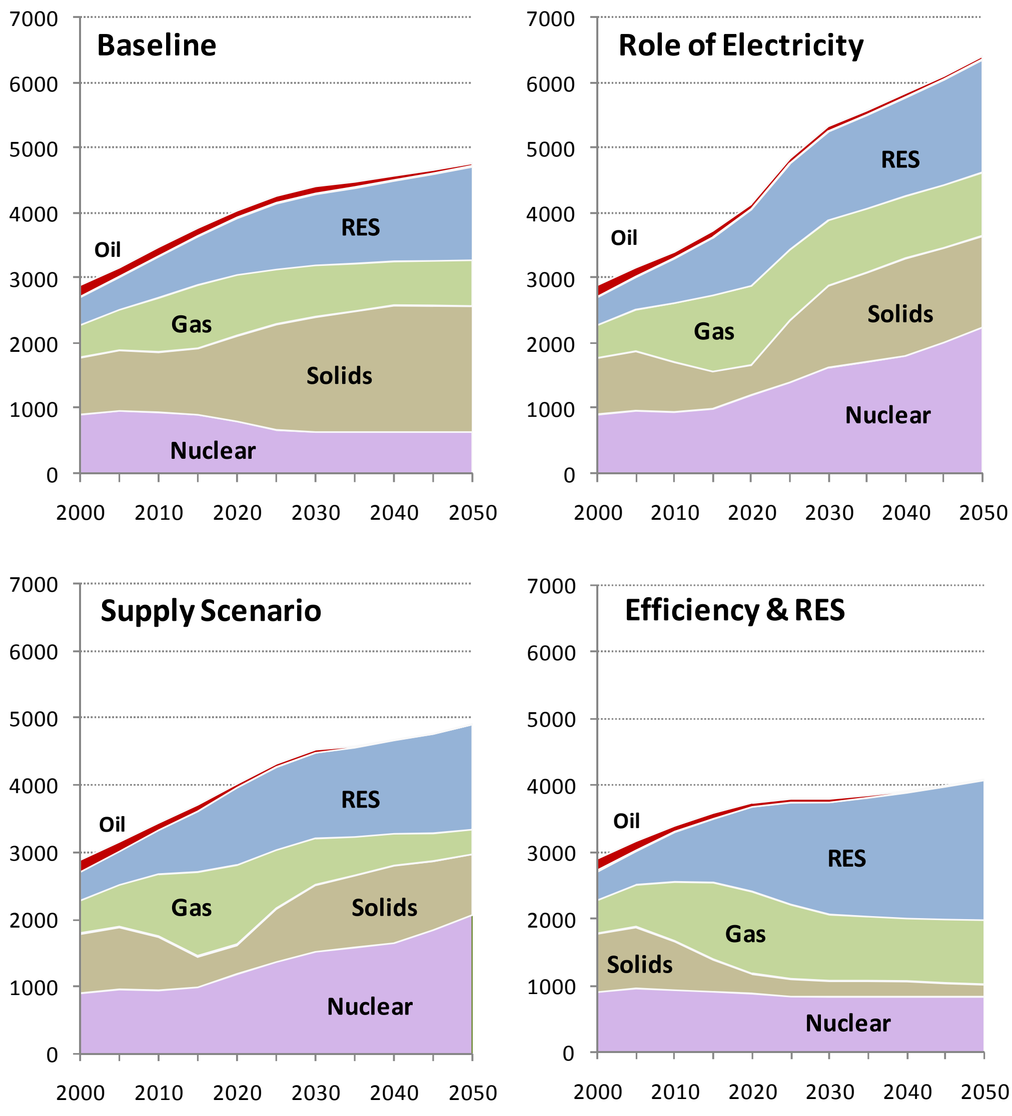
Figure 61: Structure of CO2 Emissions and of Emission Reduction - EU25



In all alternative scenarios CO2 emission reduction mainly takes place in the energy supply sectors. The "Supply Scenario" illustrates an extreme case since the energy supply sector undertakes 85.7% of total cumulative emission reduction. The "Efficiency & RES" scenario, although focusing on energy efficiency improvement still needs high abatement in energy supply. The "Role of Electricity" Scenario manages emission abatement in a different way: the electro-technologies directly contribute to emission abatement in demand sectors by substituting for fossil fuels and by improving energy efficiency and so the share of demand sectors in total emission abatement is larger than in the "Efficiency & RES" scenario.

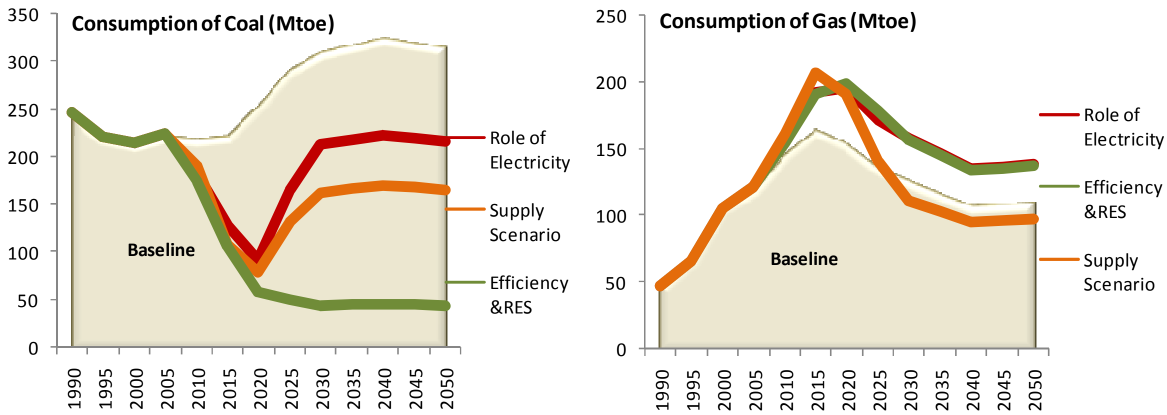
The restructuring of the power generation sector is considerable under all alternative scenarios. Gas-fired generation remains important in "Efficiency & RES" because of lack of other choices, apart from renewables. The "Role of Electricity" scenario uses all energy forms for power generation in a balanced way. Total generation in this scenario exceeds all other cases because electricity demand is substantially higher. New plants equipped with CCS, which are introduced in the "Supply Scenario" and in the "Role of Electricity" Scenario, take a share between 12 and 19% in 2030 and between 17 and 23% in 2050 allowing the re-emergence of coal-fired generation in the long term. In these two scenarios, nuclear energy also takes a considerable share in total generation, particularly in the period beyond 2030. The market penetration of renewables is significant in all scenarios but more in the “Efficiency & RES”.

Figure 62: Structure of Power Generation - EU25



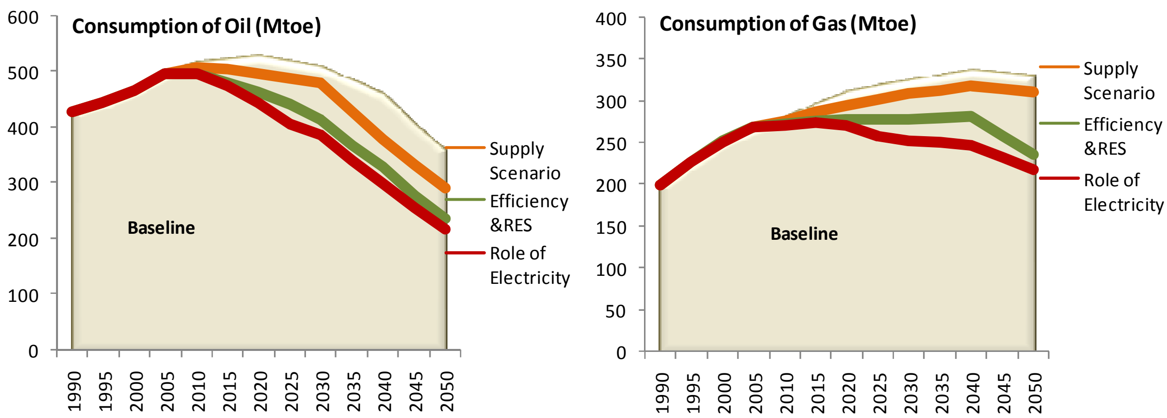
All alternative scenarios induce lower coal consumption for power generation than in the Baseline. This takes place also in the scenarios that involve CCS technology. In these scenarios, coal consumption considerably drops in the medium term and afterwards it re-emerges but stays at a lower level than in the Baseline. All alternative scenarios, and Baseline, require significant quantity of gas for power generation in the medium term, as compared with gas consumed in 2005. Except "Efficiency & RES" for which gas consumption remains at a high level throughout the projection period, the other scenarios substitute for gas in the longer term. This non uniform time profile of gas consumption undermines the possibility of the power generation sector to conclude affordable long-term gas supply contracts. This problem is bigger for the "Supply Scenario" which induces considerable decline of gas consumption in the long term. The "Role of Electricity" Scenario maintains gas consumption in the long term at a level which is higher than its level in 2005 but lower than in "Efficiency & RES".

Figure 63: Use of Gas and Coal in Power Generation - EU25



In "Role of Electricity" Scenario gas consumption in end-use sectors is reduced as a consequence of higher use of electricity through the new electro-technologies. So, although gas consumption increases in power generation, total gas consumption in this scenario is lower than Baseline and lower than in any other scenario.

Figure 64: Consumption of Oil and Gas in End-use Sectors - EU25



The demand for petroleum products declines in all alternative scenarios. The lagest decline is obtained in the context of the "Role of Electricity"

Scenario as a result of plug-in hybrid technology substitution for traditional motor engine vehicles within the transport sector.

The Baseline scenario involves a dramatic increase in Europe's dependence on energy imports. The alternative scenarios, as a result of lower energy use and shifts towards carbon-free sources, involve energy imports lower to the Baseline.

Table 14: Incremental needs for fossil fuel imports (from 2005) - EU25

Mtoe Diff. from 2005		2020	2030	2050
Baseline	Total	353	414	291
	Gas	185	196	235
	Oil	106	90	-68
	Solids	62	128	127
Efficiency & RES	Total	158	81	-107
	Gas	188	177	178
	Oil	34	-19	-192
	Solids	-64	-77	-91
Supply Scenario	Total	209	206	9
	Gas	203	165	165
	Oil	66	46	-134
	Solids	-60	-5	-20
Role of Electricity	Total	144	140	-21
	Gas	176	144	145
	Oil	18	-37	-206
	Solids	-49	34	42

This is particularly significant for oil: the level of net imports of oil, despite the decline of indigenous oil production in Europe, decreases over time in all alternative scenarios. Oil imports become lower than the 2005 level beyond 2030 in both the "Efficiency & RES" and the "Role of Electricity" scenarios.

The incremental needs (from 2005) for gas imports in the alternative scenarios also decrease against Baseline, but gas imports are generally very inelastic and therefore remain significant in all alternative scenarios. This of course is due to the fact that emission reduction is the main driver of change. In terms of incremental gas imports from 2005, the "Role of Electricity" scenario performs better than the other two scenarios. Incremental imports of coal decrease in all alternative scenarios compared to Baseline, but less so in Role of Electricity because in this scenario electricity generation is the highest among all scenarios.

The "Role of Electricity" scenario thus performs best in absolute terms (Mtoe) of incremental gas and oil net import needs from 2005.

In terms of overall dependence on oil and gas imports, in percentage terms, all alternative scenarios reduce dependence versus Baseline. The "Role of Electricity" performs better than the other two scenarios: dependence on oil and gas imports in percentage terms in 2030 approaches the 2005 level.

Table 15: Summary of Energy System Changes - EU25

Results for 2030	Baseline	Efficiency & RES	Supply Scenario	Role of Electricity
Final Energy Demand (2005=100)	118	102	113	106
Electricity Consumption (2005=100)	145	127	143	172
Electricity from Nuclear (TWh)	654	852	1535	1643
Electricity from Renewables (TWh)	1092	1675	1267	1359
CO2 Stored (cumul. Bill. tCO2)	0	0	4.8	3.6
Power Investment (cumul GW)	928	984	950	1090
Net Imports of Gas (2005=100)	188	179	174	164
Net Imports of Oil (2005=100)	116	97	108	93
Electricity Price (2005=100)	111	122	132	120
Total Energy Cost as % of GDP	9.57	10.27	10.61	9.64
CO2 Emissions (1990=100)	110	70	70	70

Results for 2050	Baseline	Efficiency & RES	Supply Scenario	Role of Electricity
Final Energy Demand (2005=100)	109	85	101	97
Electricity Consumption (2005=100)	160	138	163	212
Electricity from Nuclear (TWh)	654	852	2077	2262
Electricity from Renewables (TWh)	1437	2097	1558	1729
CO2 Stored (cumul. Bill. tCO2)	0	0	19.5	19.1
Power Investment (cumul GW)	1533	1781	1609	1979
Net Imports of Gas (2005=100)	205	180	174	165
Net Imports of Oil (2005=100)	88	66	76	63
Electricity Price (2005=100)	121	128	139	134
Total Energy Cost as % of GDP	8.83	9.28	9.59	8.99
CO2 Emissions (1990=100)	95	50	50	50

13. Decomposition of Emission Reduction

Assume a theoretical case in which energy efficiency and carbon intensity remain frozen at their base year level, throughout the outlook. In such a case CO2 emissions would have been increasing at a pace similar to GDP growth. Contrary to such a theoretical case, the Baseline Scenario projects emissions to increase at a slower pace than GDP growth. In this sense, the Baseline Scenario avoids a certain amount of CO2 emissions.

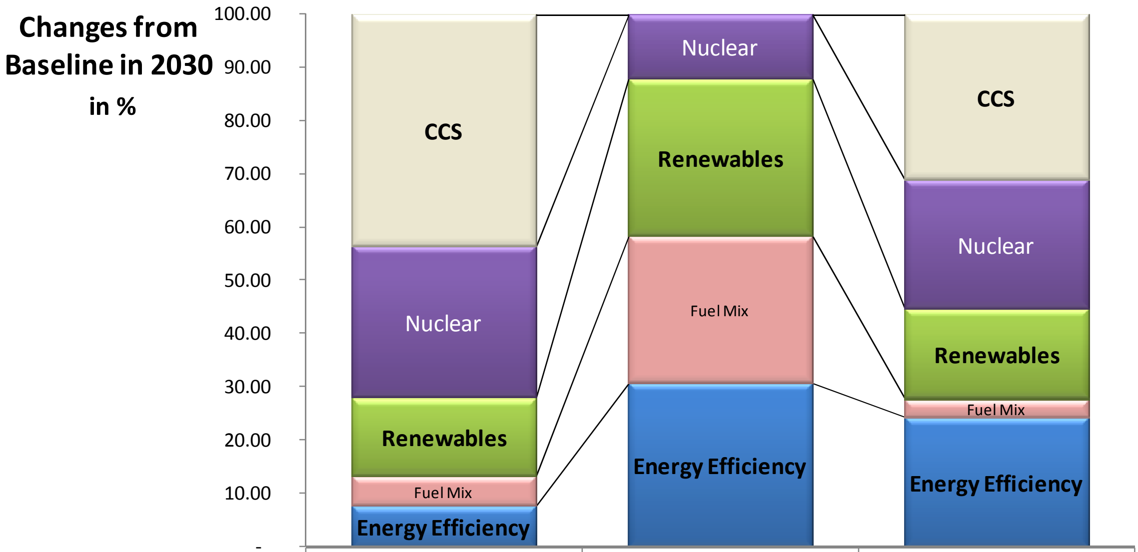
The analysis shows that the largest part of avoided CO2 emissions in the context of the Baseline Scenario is due to improvement in energy intensity, i.e. primary energy needs per unit of GDP. This improvement is approximately equal to 1.6% per year. In the context of the Baseline scenario, carbon intensity, i.e. CO2 emissions per unit of primary energy, remains rather stable implying that decarbonisation of energy consumption is not driving emission reductions.

The analysis also shows that the alternative scenarios perform better than the Baseline in terms of energy intensity improvement and in addition they involve ample restructuring of the energy system leading to drastic decarbonisation of energy consumption.

All alternative scenarios avoid emissions of carbon dioxide in equal amounts, but each scenario differs in the way it delivers carbon mitigation.

A decomposition methodology has been applied on model results to calculate the net effects of each means of carbon reduction in the context of each scenario. The decomposition applies to the CO2 emissions avoided in each scenario relative to emissions in the Baseline.

Figure 65: Decomposition of CO2 Avoided – Eu25



	Supply Scenario	Efficiency&RES	Role of Electricity
CCS	43.58	-	31.23
Nuclear	28.48	12.14	24.12
Renewables	14.55	29.57	16.96
Fuel Mix	5.74	27.42	3.42
Energy Efficiency	7.66	30.86	24.27

The "Supply Scenario" mostly relies on supply-side carbon emissions mitigation, whereas the other two scenarios show a balance between demand and supply actions. The "Fuel mix" part of the decomposition takes into account both fuel switching from coal to natural gas and the impact of deterioration of thermal efficiency as a result of the energy needed for carbon capture. However, this last effect is low compared to the overall emissions avoided.

Under the "Efficiency & RES" Scenario, power generation mostly relies on renewables and a change of the fuel mix in favour of gas to reduce emissions. It also uses more nuclear energy than Baseline: some countries that allow further expansion of nuclear undertake higher investment.

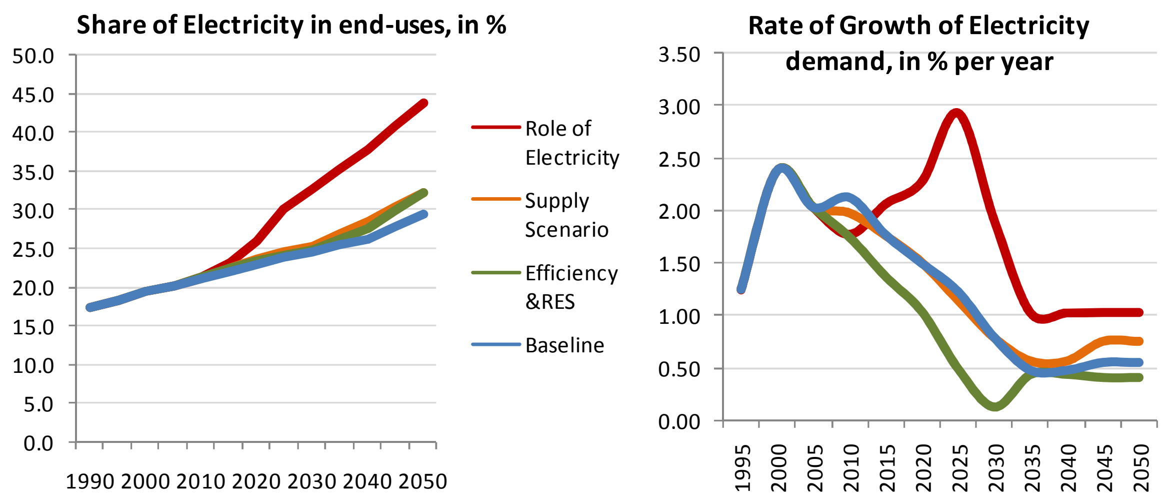
Power generation under the "Supply Scenario" mostly relies on nuclear energy and CCS, and less on renewables. Changes in the fossil-fuel mix (i.e. a shift to gas) are less pronounced in this scenario, partly because the CCS technology allows coal to re-emerge and partly because nuclear has a higher potential in this scenario.

The "Role of Electricity" scenario follows a more balanced approach regarding the relative use of the different means of reducing carbon. The scenario uses not only nuclear and CCS but also renewables in substantially higher amounts in 2030 than Supply and Baseline.

14. Conclusions for the "Role of Electricity"

The "portfolio" approach, which characterises the "Role of Electricity" scenario, explains its superior performance in terms of economic cost and carbon value. This balanced approach leads to lower economic costs because it uses every means of reducing carbon at its cost-related optimal level. Excluding an option for carbon-reduction would imply that in order to achieve the same overall amount of CO_2 emissions reductions, some other options will have to be used at non-optimal cost levels.

Figure 66: Demand for Electricity - EU25



This is not, however, the only reason why the "Role of Electricity" scenario performs better in terms of both costs and carbon value. This scenario also maximises the benefits of the portfolio approach because it allows higher cost-effective emissions reduction through greater penetration of efficient electric appliances, electric vehicles, lighting, etc, combined with the transformation of the power sector into a low-carbon energy conversion system. This scenario captures the benefits of advanced electro-technologies (plug-in hybrid vehicles, heat pumps, etc.) for which the "Role of Electricity" scenario assumes a significant degree of market-acceptance and technological success. The role of these electro-technologies justifies the term "intelligent use of electricity" as they promote energy efficiency in specific electricity uses combined with higher use of electricity in thermal and transport uses.

The results for each scenario are evaluated with respect to the basic energy policy goals of the European Union: economic competitiveness, environmental protection and security of supply. The Baseline scenario is the best with respect to economic cost but fails to address the environmental and security of supply issues.

Table 16: Overall Performance of Scenarios

Index (2005=100) (*)	**Total Cost of Energy**		**Dependence on Imported Oil & Gas**		**CO_2 Emissions from Energy**	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**
Baseline	146	159	126	138	110	95
Efficiency & RES	156	164	128	137	70	50
Supply Scenario	161	169	115	114	70	50
Role of Electricity	147	164	105	102	70	50

For equal environmental constraints, the "Role of Electricity" scenario performs better than the other scenarios in terms of economic competitiveness and Europe's dependence on sensitive imports.

A series of sensitivity analyses have been carried out with the models to check the robustness of these results. Among other sensitivity analyses, scenarios involving higher oil and gas prices have been quantified. The results support the same hierarchy of the alternative scenarios.

15. Economic Implications

As mentioned, the cost implications of emissions mitigation under the different scenarios show the advantage of the Role of Electricity scenario resulting from the supply "portfolio" approach combined with the "intelligent" use of electricity on the demand side.

The additional costs incurred under the "Role of Electricity" scenario are reasonable: the total cost of energy as a percentage of GDP increases slightly from Baseline, while the other two scenarios involve a significant increase in this percentage. Investment requirements for the power system and electricity prices increase from Baseline but the energy bill to be paid by final consumers is the smallest among the carbon reducing scenarios and clearly affordable when compared to Baseline.

The “Role of Electricity” scenario holds greater promise for economic development in view of its lower energy costs and is also more robust because its reliance on a broader portfolio of supply and demand solutions allows the system to better absorb unexpected changes or developments.

It is important to underline that all three alternative scenarios replace the transfer of funds abroad to pay for imported energy with higher investments and other costs that are paid to domestic European sectors, such as the equipment goods industry. This substitution has positive effects on economic growth. Also the additional spending in investment concern new advanced technologies. If they are facilitated by the EU internal market to reach economic and technical maturity they will provide new growth opportunities for Europe through higher exports to third countries.

However, all three scenarios imply higher expenses in the energy sector that must be financed by the rest of the economy. Since energy is a “material” production sector, it usually has a lower multiplier effect than other sectors. Accordingly, higher cost of energy exerts negative impacts on economic growth.

The “Role of Electricity” scenario relies less on imported energy than other scenarios and at the same time implies that the rest of the economy bears lower additional costs than those resulting from the other emission reducing scenarios. Therefore, this scenario has an overall better performance in terms of economic growth implications.

However, the net long-term effect on economic growth will depend on the technological and industrial dynamics of Europe: energy and environmental restructuring under certain conditions of economic and industrial policy may well trigger “endogenous” economic growth, employment and exports of equipment goods and services. In summary, it has to be underlined that energy restructuring, despite the high cost, could lead to equal or even higher GDP growth.

16. Overall Performance of Scenarios

The Baseline scenario clearly represents a non-sustainable future in terms of environmental impact (climate change) and security of supply (import dependence).

The Baseline scenario could improve if the nuclear option was unlocked (i.e. no phase-out and extension of lifetime) and if energy efficiency and renewables policies were to prove more effective.

Under an ambitious CO2 emissions-reduction target of -30% in 2030 versus 1990 levels and -50% in 2050, an electricity-related package of low-carbon solutions on both the demand and supply sides can be extremely cost-effective.

This electricity-related package delivers considerable benefits by reducing import dependence on oil and gas. The package promotes high technological progress in all electricity domains and can induce positive economic growth effects. The package does imply an additional cost to consumers, but this is reasonable and optimized.

In this package, higher but intelligent use of electricity on the demand side is combined with very low- carbon power generation: this is the key to cost-effectiveness. This is made possible by the success of a series of technologies and policies, such as:

- Plug-in hybrid vehicles
- Heat pumps, efficient lighting etc.
- Ambitious development of energy efficiency
- Higher potential of renewables
- Carbon capture and storage
- Nuclear energy

The cost-effectiveness of the electricity-related package relies on its balanced "portfolio" approach and on the intelligent use of electricity. All options, for both demand and supply, must be kept open so as to exploit their highest cost-effective potential. Approaches that exclude certain options are not cost-effective.

The sensitivity analyses, the long-run (up to 2050) projections and also scenarios that assume very high fossil-fuel prices confirm the above results and demonstrate their robustness.

Appendix – Tables

Table 17: Baseline Scenario - Energy Balance - EU25

EU25 - PRIMES Model	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Mtoe													
Primary Energy Needs													
Primary energy	1556	1572	1654	1741	1810	1856	1881	1869	1876	1837	1798	1762	1726
Primary energy	1556	1572	1654	1741	1810	1856	1881	1869	1876	1858	1849	1840	1844
Solids	432	345	307	305	292	289	315	347	362	366	370	366	362
Oil	596	621	635	647	667	667	664	643	636	580	530	477	430
Gas	261	308	376	421	458	498	507	500	500	497	495	493	491
Nuclear	197	215	238	252	247	237	211	177	169	169	169	168	169
Renewables	69	81	96	114	144	163	182	200	208	244	283	334	391
Primary Energy Supply													
Indigenous production	878	897	899	887	835	739	682	642	619	633	658	680	717
Dom. Non Fossil	268	298	336	369	393	402	395	379	379	414	454	504	562
Dom. Solids	352	264	204	190	155	139	137	129	119	120	121	120	119
Dom. Oil	120	162	164	134	117	75	53	48	44	26	16	9	6
Dom. Gas	140	174	197	197	172	125	98	89	80	74	69	48	33
Net Imports	711	701	801	899	1023	1168	1252	1281	1312	1281	1249	1222	1190
Imp. Solids	75	74	94	115	137	150	177	218	243	246	249	246	243
Imp Oil	510	491	518	558	598	642	664	649	648	612	574	531	490
Imp Gas	124	135	186	223	286	373	408	412	420	423	426	445	458
Other uses			184	187	188	189	189	180	185	181	182	218	255
Solids			35	31	27	24	21	18	18	18	17	20	23
Oil			125	117	118	117	114	103	105	80	56	61	63
Gas			19	31	32	36	41	46	48	49	49	49	50
Nuclear			0	0	0	0	0	0	0	0	0	0	0
Renewables			5	8	11	12	13	13	14	35	59	88	120
Power Generation	211	224	249	273	300	325	348	368	380	386	394	402	411
Nuclear	67	74	79	84	82	79	70	59	56	56	56	56	56
Renewables	26	31	37	43	54	64	75	87	94	100	106	115	124
Solids			75	80	79	87	113	139	152	159	167	166	166
Gas			43	54	72	85	81	73	69	64	59	60	62
Oil			15	12	12	10	9	9	9	7	6	4	4
(Biomass)			5	7	9	11	16	19	19	23	28	33	39
(Non thermal RES)			31	36	45	52	59	68	75	77	78	82	85
Fuels in Power	353	349	383	402	429	451	474	498	506	508	514	521	532
Solids	246	221	214	224	220	223	256	293	310	318	325	320	315
Oil	49	49	42	33	32	28	22	22	21	17	13	10	8
Gas	47	65	105	119	146	164	154	136	126	117	108	109	110
Biomass	10	14	21	26	31	35	43	48	48	58	68	82	99
Average Efficiency			0.36	0.38	0.40	0.43	0.46	0.48	0.49	0.50	0.50	0.51	0.51
Solids			0.35	0.36	0.36	0.39	0.44	0.48	0.49	0.50	0.51	0.52	0.53
Gas			0.41	0.46	0.50	0.51	0.53	0.54	0.55	0.55	0.55	0.55	0.56
Oil			0.36	0.36	0.36	0.37	0.42	0.42	0.43	0.44	0.44	0.45	0.45
Biomass			0.26	0.26	0.28	0.32	0.37	0.39	0.40	0.40	0.41	0.40	0.39
Power Generation (TWh)			2906	3176	3487	3782	4050	4275	4420	4493	4583	4674	4777
Nuclear			921	978	957	921	817	686	654	654	654	654	654
Renewables			428	499	630	742	870	1012	1092	1161	1235	1332	1437
Solids			875	929	921	1015	1314	1621	1766	1852	1941	1936	1930
Gas			504	631	843	984	942	850	801	742	687	701	715
Oil			177	138	135	120	107	106	108	85	67	52	41
(Biomass)			63	80	103	132	185	220	224	269	322	380	448
(Non thermal RES)			364	419	528	610	684	792	868	892	912	952	989
Energy Consumption by sector	1022	1036	1095	1168	1238	1293	1341	1363	1374	1364	1355	1312	1274
Industry	341	317	330	339	357	373	383	389	393	374	357	329	304
- energy intensive	217	203	212	215	221	227	229	228	226	213	201	185	170
- other industry	124	114	118	125	136	146	154	162	167	161	156	144	134
Residential	261	275	273	295	312	328	339	347	352	357	362	370	378
Tertiary	147	149	159	174	189	201	213	221	227	236	245	249	252
Transport	273	295	333	361	381	390	405	406	402	396	391	364	339
Energy Consumption by fuel	1022	1036	1095	1168	1238	1293	1341	1363	1374	1364	1355	1311	1273
Solids	124	80	57	50	45	42	39	36	34	31	28	25	23
Oil	428	446	468	497	517	522	528	519	509	484	461	407	359
Gas	200	227	252	270	280	298	312	319	326	332	338	335	331
Electricity	176	188	211	234	260	284	306	325	338	346	355	364	375
Distr. Heat	63	60	69	74	80	85	89	94	96	97	97	97	98
Other (RES)	30	35	38	43	56	63	68	70	71	74	77	82	88

Table 18: "Efficiency & RES" Scenario - Energy Balance - EU25

EU25 - PRIMES Model	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Mtoe													
Primary Energy Needs													
Primary energy	1556	1572	1654	1743	1744	1721	1697	1663	1629	1594	1561	1503	1448
Primary energy	1556	1572	1654	1743	1744	1721	1697	1663	1629	1628	1639	1624	1629
Solids	432	345	307	305	241	162	103	88	74	71	68	59	51
Oil	596	621	635	648	635	616	591	555	526	472	423	362	310
Gas	261	308	376	421	456	499	511	496	479	478	478	456	435
Nuclear	197	215	238	252	245	239	232	221	220	221	222	226	232
Renewables	69	81	96	114	164	203	257	300	328	384	446	519	599
Primary Energy Supply													
Indigenous production	878	897	899	888	838	723	691	699	703	737	784	830	895
Dom. Non Fossil	268	298	336	369	412	444	491	523	550	607	670	747	833
Dom. Solids	352	264	204	190	142	83	53	44	36	34	33	30	26
Dom. Oil	120	162	164	134	116	73	51	46	41	25	15	9	5
Dom. Gas	140	174	197	197	171	125	98	88	79	73	68	47	32
Net Imports	711	701	801	901	954	1049	1059	1018	981	946	911	851	793
Imp. Solids	75	74	94	115	99	79	51	44	38	37	35	29	24
Imp Oil	510	491	518	559	568	594	593	563	540	504	467	413	366
Imp Gas	124	135	186	224	285	374	413	408	401	405	410	409	402
Other uses			184	187	193	195	193	187	191	226	265	306	355
Solids			35	31	27	23	19	17	14	14	13	12	11
Oil			125	118	117	116	112	100	100	95	89	80	71
Gas			19	31	29	32	33	39	44	45	46	46	45
Nuclear			0	0	0	0	0	0	0	1	2	6	12
Renewables			5	8	19	25	28	31	34	72	114	162	216
Power Generation	211	224	249	273	293	310	323	328	328	333	338	346	354
Nuclear	67	74	79	84	82	80	77	74	73	73	73	73	73
Renewables	26	31	37	43	64	81	109	131	144	153	162	171	180
Solids	0	0	75	79	63	41	25	22	20	20	20	17	15
Gas	0	0	43	55	77	100	107	97	86	84	82	83	84
Oil	0	0	15	12	8	8	5	5	5	3	2	1	1
(Biomass)			5	7	10	16	32	41	45	50	55	62	69
(Non thermal RES)			31	36	54	65	77	91	99	103	106	109	111
Fuels in Power	353	349	383	404	382	361	346	335	314	318	325	339	357
Solids	246	221	214	224	174	105	58	50	44	42	40	35	30
Oil	49	49	42	33	20	20	13	12	11	7	5	3	2
Gas	47	65	105	121	155	191	199	179	157	153	150	152	153
Biomass	10	14	21	26	33	45	75	94	102	115	131	150	171
Average Efficiency			0.36	0.38	0.41	0.46	0.49	0.49	0.50	0.49	0.49	0.48	0.47
Solids			0.35	0.35	0.36	0.39	0.44	0.44	0.46	0.48	0.49	0.50	0.51
Gas			0.41	0.45	0.50	0.52	0.54	0.54	0.55	0.55	0.55	0.55	0.55
Oil			0.36	0.37	0.38	0.40	0.41	0.41	0.41	0.42	0.42	0.42	0.42
Biomass			0.26	0.26	0.30	0.36	0.42	0.43	0.44	0.43	0.42	0.41	0.40
Power Generation (TWh)			2906	3175	3407	3605	3758	3819	3820	3871	3936	4019	4114
Nuclear			921	978	951	928	900	856	852	852	852	852	852
Renewables			428	499	741	947	1262	1524	1675	1775	1881	1986	2097
Solids			875	916	730	479	294	259	237	233	229	203	180
Gas			504	638	896	1160	1239	1123	1001	975	949	962	974
Oil			177	143	89	91	62	57	55	36	24	16	10
(Biomass)			63	79	116	192	367	472	519	578	643	720	806
(Non thermal RES)			364	420	624	755	896	1053	1156	1198	1238	1266	1292
Energy Consumption by sector	1022	1036	1095	1168	1203	1217	1226	1218	1193	1158	1126	1058	999
Industry	341	317	330	339	350	357	359	362	362	333	306	266	231
- energy intensive	217	203	212	215	216	216	211	207	202	184	167	144	125
- other industry	124	114	118	125	134	142	148	155	160	149	139	121	106
Residential	261	275	273	295	303	310	313	312	307	316	325	326	327
Tertiary	147	149	159	174	180	185	189	188	181	186	192	192	193
Transport	273	295	333	361	369	365	365	356	343	323	304	274	248
Energy Consumption by fuel	1022	1036	1095	1168	1203	1217	1226	1218	1193	1157	1126	1057	999
Solids	124	80	57	50	40	33	26	21	17	16	15	12	10
Oil	428	446	468	497	498	481	466	443	414	369	329	279	237
Gas	200	227	252	269	272	277	279	279	279	280	282	258	237
Electricity	176	188	211	234	255	273	287	295	297	303	310	316	323
Distr. Heat	63	60	69	74	80	85	92	95	95	95	96	94	92
Other (RES)	30	35	38	44	59	68	77	85	93	94	95	98	101

Table 19: "Supply Scenario" - Energy Balance - EU25

EU25 - PRIMES Model	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Mtoe													
Primary Energy Needs													
Primary energy	1556	1572	1654	1744	1779	1792	1825	1868	1914	1882	1851	1837	1823
Primary energy	1556	1572	1654	1744	1779	1792	1825	1868	1914	1917	1935	1969	2026
Solids	432	345	307	305	258	164	124	172	199	208	218	196	176
Oil	596	621	635	649	653	646	624	600	593	531	475	419	370
Gas	261	308	376	421	465	526	526	488	468	457	445	433	421
Nuclear	197	215	238	252	249	260	311	356	396	413	429	480	536
Renewables	69	81	96	114	151	193	237	250	255	308	366	440	522
Primary Energy Supply													
Indigenous production	878	897	899	888	837	740	768	825	862	911	974	1063	1176
Dom. Non Fossil	268	298	336	369	402	456	550	608	653	722	797	922	1060
Dom. Solids	352	264	204	189	150	88	69	85	89	92	95	88	80
Dom. Oil	120	162	164	134	116	74	52	47	43	26	16	9	6
Dom. Gas	140	174	197	197	172	125	98	88	79	73	68	47	32
Net Imports	711	701	801	901	989	1102	1110	1097	1107	1061	1017	964	910
Imp. Solids	75	74	94	115	109	76	55	87	110	116	122	108	95
Imp Oil	510	491	518	560	585	623	625	607	606	562	518	470	426
Imp Gas	124	135	186	224	293	401	427	400	389	383	377	386	389
Other uses			184	188	188	189	189	179	183	227	270	316	367
Solids			35	31	27	23	19	17	15	17	18	20	22
Oil			125	118	121	120	114	100	101	98	93	85	78
Gas			19	30	28	32	39	46	49	52	51	51	51
Nuclear			0	0	0	0	0	0	0	0	0	0	0
Renewables			5	8	12	14	16	17	18	60	108	159	217
Power Generation	211	224	249	273	297	320	347	372	390	394	403	410	422
Nuclear	67	74	79	84	83	87	104	119	132	137	143	160	179
Renewables	26	31	37	43	56	77	99	106	109	114	119	126	134
Solids	0	0	75	79	68	39	37	68	85	92	99	87	77
Gas	0	0	43	55	81	109	103	76	60	50	41	36	32
Oil	0	0	15	12	9	8	5	4	4	2	1	0	0
(Biomass)			5	7	9	19	29	30	30	34	38	42	47
(Non thermal RES)			31	36	47	58	69	76	79	80	82	84	87
Fuels in Power	353	349	383	404	408	387	354	355	354	349	353	335	323
Solids	246	221	214	223	191	108	79	131	162	172	183	161	141
Oil	49	49	42	33	24	21	12	11	10	4	2	1	1
Gas	47	65	105	122	161	207	191	140	111	92	76	68	60
Biomass	10	14	21	26	33	52	72	73	71	81	92	106	121
Average Efficiency			0.36	0.38	0.41	0.45	0.49	0.50	0.51	0.51	0.51	0.50	0.48
Solids			0.35	0.35	0.35	0.36	0.46	0.52	0.52	0.53	0.54	0.54	0.55
Gas			0.41	0.45	0.50	0.53	0.54	0.54	0.54	0.54	0.54	0.54	0.53
Oil			0.36	0.37	0.38	0.41	0.41	0.41	0.42	0.41	0.40	0.39	0.38
Biomass			0.26	0.26	0.29	0.37	0.41	0.42	0.42	0.41	0.41	0.40	0.39
Power Generation (TWh)			2906	3175	3453	3723	4031	4330	4535	4585	4683	4771	4911
Nuclear			921	978	965	1009	1206	1382	1535	1597	1662	1858	2077
Renewables			428	499	656	900	1148	1231	1267	1325	1385	1469	1558
Solids			875	916	787	448	425	787	987	1064	1147	1017	901
Gas			504	639	940	1268	1196	879	699	579	480	423	372
Oil			177	142	106	98	56	51	47	20	9	5	3
(Biomass)			63	80	109	224	342	352	348	390	437	487	543
(Non thermal RES)			364	419	547	676	806	879	919	935	948	982	1015
Energy Consumption by sector	1022	1036	1095	1168	1222	1258	1286	1308	1324	1283	1244	1211	1181
Industry	341	317	330	339	352	363	367	372	376	354	334	314	295
- energy intensive	217	203	212	215	217	218	215	213	212	198	184	173	162
- other industry	124	114	118	125	135	145	152	159	164	157	149	141	133
Residential	261	275	273	295	307	319	324	332	338	341	344	353	361
Tertiary	147	149	159	174	185	194	201	208	215	217	219	224	229
Transport	273	295	333	361	378	383	394	396	395	371	348	321	296
Energy Consumption by fuel	1022	1036	1095	1168	1222	1258	1286	1308	1324	1281	1244	1209	1181
Solids	124	80	57	50	40	33	26	24	22	19	17	15	13
Oil	428	446	468	497	509	506	499	490	482	428	380	333	291
Gas	200	227	252	269	276	287	295	302	308	313	318	314	310
Electricity	176	188	211	234	258	281	303	321	334	343	353	367	381
Distr. Heat	63	60	69	74	79	82	83	87	91	91	91	90	89
Other (RES)	30	35	38	44	59	69	80	85	87	86	85	91	97

Table 20: "Role of Electricity" Scenario - Energy Balance - EU25

EU25 - PRIMES Model	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Mtoe													
Primary Energy Needs													
Primary energy	1556	1572	1654	1742	1749	1751	1766	1814	1881	1865	1850	1843	1837
Primary energy	1556	1572	1654	1742	1749	1751	1766	1814	1881	1892	1915	1943	1990
Solids	432	345	307	305	250	185	139	209	253	269	285	275	266
Oil	596	621	635	648	635	612	574	524	507	449	398	344	297
Gas	261	308	376	421	455	497	497	463	446	438	430	415	400
Nuclear	197	215	238	252	247	260	314	365	424	446	470	524	583
Renewables	69	81	96	114	159	196	239	251	248	287	329	383	441
Primary Energy Supply													
Indigenous production	878	897	899	887	839	747	775	847	896	941	996	1074	1170
Dom. Non Fossil	268	298	336	369	409	458	556	619	675	737	802	910	1027
Dom. Solids	352	264	204	190	146	94	73	99	104	109	114	111	108
Dom. Oil	120	162	164	134	116	73	50	45	41	25	15	9	5
Dom. Gas	140	174	197	197	171	125	98	87	79	73	68	47	32
Net Imports	711	701	801	900	958	1055	1044	1021	1041	1006	975	927	879
Imp. Solids	75	74	94	116	104	91	67	110	150	160	171	164	158
Imp Oil	510	491	518	559	568	590	577	533	521	482	442	395	353
Imp Gas	124	135	186	223	284	372	399	375	367	365	362	368	368
Other uses			184	187	192	194	190	179	180	200	221	245	270
Solids			35	31	27	23	20	18	16	18	20	24	27
Oil			125	118	118	117	113	102	103	95	87	78	69
Gas			19	30	28	30	30	32	35	35	36	36	35
Nuclear			0	0	0	0	0	0	0	0	0	0	0
Renewables			5	8	18	24	27	27	27	52	79	108	139
Power Generation	211	224	249	273	294	321	357	417	460	481	503	526	552
Nuclear	67	74	79	84	82	87	105	122	141	149	157	175	195
Renewables	26	31	37	43	59	76	101	113	117	123	130	139	149
Solids	0	0	75	79	67	50	40	82	108	118	129	125	121
Gas	0	0	43	55	78	101	105	93	87	84	82	83	84
Oil	0	0	15	12	8	8	7	6	7	6	5	4	4
(Biomass)			5	7	9	16	27	31	30	34	39	44	50
(Non thermal RES)			31	36	50	60	74	83	87	89	91	95	99
Fuels in Power	353	349	383	403	392	386	369	425	456	474	494	497	502
Solids	246	221	214	224	183	128	91	165	212	227	243	233	223
Oil	49	49	42	32	21	20	16	15	16	13	12	10	9
Gas	47	65	105	121	156	192	196	172	158	152	147	147	147
Biomass	10	14	21	26	32	45	66	73	70	81	92	107	123
Average Efficiency			0.36	0.38	0.41	0.45	0.48	0.50	0.51	0.51	0.52	0.52	0.52
Solids			0.35	0.35	0.36	0.39	0.44	0.50	0.51	0.52	0.53	0.54	0.54
Gas			0.41	0.45	0.50	0.52	0.54	0.54	0.55	0.55	0.56	0.57	0.57
Oil			0.36	0.37	0.38	0.41	0.41	0.41	0.42	0.42	0.43	0.43	0.44
Biomass			0.26	0.26	0.28	0.35	0.41	0.42	0.43	0.42	0.42	0.41	0.40
Power Generation (TWh)			2906	3175	3416	3737	4151	4849	5346	5587	5850	6117	6418
Nuclear			921	978	959	1007	1219	1414	1643	1731	1823	2031	2262
Renewables			428	498	686	883	1173	1320	1359	1432	1509	1616	1729
Solids			875	921	774	580	468	958	1261	1376	1502	1454	1407
Gas			504	639	905	1170	1216	1086	1007	982	957	966	976
Oil			177	139	92	97	76	71	76	66	58	50	44
(Biomass)			63	79	106	185	314	358	347	396	452	512	580
(Non thermal RES)			364	419	580	698	859	962	1012	1036	1057	1103	1149
Energy Consumption by sector	1022	1036	1095	1168	1203	1220	1227	1223	1234	1207	1185	1155	1131
Industry	341	317	330	339	351	358	360	362	367	348	329	304	280
- energy intensive	217	203	212	215	217	217	214	212	212	199	186	171	157
- other industry	124	114	118	125	134	141	146	150	155	149	143	133	123
Residential	261	275	273	295	303	312	317	320	323	333	345	359	373
Tertiary	147	149	159	174	180	187	193	197	202	209	216	224	233
Transport	273	295	333	361	368	363	358	345	342	318	295	268	244
Energy Consumption by fuel	1022	1036	1095	1168	1203	1220	1227	1223	1234	1206	1185	1153	1131
Solids	124	80	57	50	40	34	27	26	25	24	22	19	16
Oil	428	446	468	497	496	475	445	407	389	341	299	256	219
Gas	200	227	252	269	271	275	272	258	253	250	248	232	218
Electricity	176	188	211	234	255	283	317	366	402	424	446	470	494
Distr. Heat	63	60	69	74	81	88	94	98	101	102	103	103	103
Other (RES)	30	35	38	43	59	66	72	69	64	65	67	73	80

Table 21: Baseline Scenario – Power Capacity - EU25

GW	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Power Capacity	662	734	812	876	959	1054	1117	1130	1153	1197	1252
Nuclear	141	137	136	123	108	83	81	81	81	81	81
Renewables	126	158	203	244	290	342	380	413	453	499	555
Solids	189	190	169	183	230	281	303	314	325	323	320
Gas	132	170	235	265	281	302	313	290	269	275	280
Oil	74	79	69	61	51	45	40	32	25	20	16
Hydro	97	100	104	107	109	111	113	113	114	116	117
Wind onshore	13	37	66	90	110	131	144	147	150	152	155
Wind offshore	0	1	8	11	17	33	48	56	67	79	93
Solar and Other	1	2	3	5	7	9	12	15	18	24	32
Biomass	14	18	22	31	47	58	63	81	104	128	158

GW	00-05	.05-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
Power Investment	105	142	140	185	189	167	135.2	153.4	146.7	169.3
Nuclear	2.6	1.6	1.6	3.0	7.7	34.1	21.1	11.7	1.6	1.6
Renewables	33.1	47.3	45.9	51.7	58.9	59.8	68.6	87.0	87.5	104.1
Solids	13.6	15.6	45.7	87.7	80.1	38.3	26.3	24.6	15.2	15.9
Gas	40.6	73.1	42.2	35.9	38.0	31.4	18.7	29.8	42.1	47.4
Oil	15.3	4.0	5.0	6.7	4.2	3.3	0.5	0.3	0.3	0.3
Hydro	2.8	4.1	2.9	2.0	2.2	1.5	1.0	1.0	1.5	1.5
Wind onshore	23.9	29.5	26.6	24.2	25.0	33.0	21.4	26.6	26.3	35.2
Wind offshore	1.0	7.3	2.7	5.5	16.6	15.6	17.0	22.4	19.2	16.7
Solar and Other	1.2	0.9	1.3	2.2	2.5	3.3	8.2	9.0	13.4	13.1
Biomass	4.2	5.5	12.4	17.9	12.5	6.4	21.1	28.0	27.2	37.6

Table 22: "Efficiency & RES" Scenario – Power Capacity - EU25

GW	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Power Capacity	662	729	837	916	1024	1104	1173	1220	1294	1302	1313
Nuclear	141	137	136	125	119	105	106	106	106	106	106
Renewables	126	158	235	307	421	525	604	682	784	792	800
Solids	189	186	164	157	128	100	89	79	70	65	60
Gas	132	171	238	270	312	337	344	332	320	331	341
Oil	74	76	65	56	44	37	31	20	14	9	6
Hydro	97	100	107	109	110	113	115	116	117	118	119
Wind onshore	13	37	87	119	142	167	183	184	186	188	190
Wind offshore	0	1	11	30	50	66	80	98	120	121	123
Solar and Other	1	2	5	8	36	69	107	119	133	135	138
Biomass	14	18	25	42	83	109	119	165	229	230	230

GW	00-05	.05-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
Power Investment	99.73	172.5	155.7	209.5	173.9	173	190.7	234.4	201.7	170.2
Nuclear	2.6	1.6	3.4	11.8	19.0	37.4	21.1	11.7	1.6	3.4
Renewables	33.3	78.6	77.3	120.2	110.4	100.6	118.8	167.4	145.7	111.0
Solids	10.0	14.1	25.5	11.4	1.5	4.4	17.7	12.4	4.9	0.4
Gas	41.6	75.0	45.0	61.9	40.8	28.2	29.3	40.2	47.6	54.1
Oil	12.2	3.2	4.4	4.2	2.2	2.4	3.9	2.7	1.8	1.3
Hydro	3.0	7.0	1.9	1.4	2.9	1.7	0.9	0.9	1.2	1.2
Wind onshore	23.9	51.1	33.4	27.4	30.1	34.6	20.5	25.7	42.7	45.4
Wind offshore	1.0	9.8	18.8	20.0	16.4	15.0	28.7	52.5	11.3	20.3
Solar and Other	1.2	2.8	2.6	28.7	33.0	38.2	19.3	19.0	86.0	31.5
Biomass	4.2	7.9	20.6	42.7	28.1	11.1	49.5	69.3	4.5	12.6

Table 23: "Supply Scenario" – Power Capacity - EU25

GW	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Power Capacity	662	728	818	903	1040	1149	1218	1198	1198	1206	1227
Nuclear	141	137	138	136	157	180	199	208	216	241	269
Renewables	126	158	213	291	389	431	451	475	502	535	574
Solids	189	185	155	128	137	179	202	217	233	207	183
Gas	132	170	247	291	314	324	336	285	241	219	200
Oil	74	77	65	57	43	36	29	13	6	4	2
Hydro	97	100	104	107	109	110	112	113	113	115	116
Wind onshore	13	37	72	108	135	148	154	154	155	157	158
Wind offshore	0	1	10	23	35	48	53	59	65	73	82
Solar and Other	1	2	3	5	33	41	45	52	60	69	81
Biomass	14	18	24	49	77	85	87	97	109	122	137

GW	00-05	.05-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
Power Investment	98.8	152.2	151.2	222.1	177.2	148.7	194.1	183.5	135.1	146.8
Nuclear	2.6	1.6	1.9	22.6	29.8	32.4	84.1	43.7	26.7	29.8
Renewables	33.4	56.7	83.3	103.9	48.2	42.7	61.2	85.2	81.6	102.5
Solids	9.5	5.6	5.2	49.0	71.6	38.4	30.9	32.7	6.2	3.4
Gas	40.4	85.0	56.9	43.1	25.9	33.4	11.7	19.1	19.5	10.5
Oil	13.0	3.3	4.0	3.4	1.7	1.7	6.2	2.8	1.0	0.5
Hydro	2.8	4.1	2.9	1.7	1.4	1.7	0.7	0.7	1.2	1.3
Wind onshore	23.9	36.0	37.4	31.6	17.5	25.0	19.6	24.8	30.1	31.3
Wind offshore	1.0	9.0	12.9	12.7	12.0	7.0	15.3	29.7	17.3	19.6
Solar and Other	1.2	0.9	1.4	28.4	7.6	4.7	12.2	13.4	16.4	19.9
Biomass	4.4	6.8	28.7	29.6	9.6	4.2	13.4	16.5	16.6	30.4

Table 24: "Role of Electricity" – Power Capacity - EU25

GW	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Power Capacity	662	732	830	915	1067	1242	1358	1411	1473	1543	1627
Nuclear	141	137	138	136	156	178	213	224	236	263	292
Renewables	126	158	217	285	394	453	481	516	557	608	667
Solids	189	188	169	163	151	205	241	259	278	268	258
Gas	132	171	238	271	319	365	388	380	373	381	389
Oil	74	78	68	60	47	40	35	31	27	24	21
Hydro	97	100	105	108	110	112	114	115	115	117	119
Wind onshore	13	37	76	110	135	156	168	169	170	172	174
Wind offshore	0	1	11	20	42	57	63	69	75	84	93
Solar and Other	1	2	5	8	34	42	45	55	68	81	98
Biomass	14	17	21	40	72	87	91	108	128	153	183

GW	00-05	.05-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
Power Investment	102.9	160.3	150.7	237.3	242.5	196.6	234.6	229.1	215.9	208.8
Nuclear	2.6	1.6	1.9	21.6	28.5	48.0	87.4	47.3	28.1	31.3
Renewables	33.1	61.4	72.4	115.2	65.8	50.2	74.7	96.5	132.8	118.3
Solids	11.9	17.5	26.0	28.3	83.4	51.9	33.5	37.9	7.2	5.7
Gas	40.9	75.9	45.5	68.1	62.0	43.4	34.2	44.2	45.6	52.0
Oil	14.4	4.0	4.9	4.0	2.9	3.1	4.7	3.3	2.2	1.5
Hydro	2.9	5.0	2.7	1.9	2.4	1.7	0.9	0.9	1.6	1.6
Wind onshore	23.9	40.3	35.3	30.1	25.5	31.1	19.9	25.1	33.8	31.2
Wind offshore	1.0	9.5	9.3	22.7	14.2	7.3	16.5	27.4	18.0	16.9
Solar and Other	1.2	2.6	2.7	26.6	7.4	3.8	17.3	18.2	52.2	26.9
Biomass	4.1	4.0	22.4	33.9	16.4	6.3	20.2	25.0	27.2	41.8

Table 25: Baseline Scenario – Electricity in Demand Sectors – EU25

Mtoe	2000	2005	2010	2015	2020	2025	2030
Industry							
Total Final Energy	330	339	357	373	383	389	393
Total Electricity	90	96	103	110	114	119	122
Electricity in Thermal Uses	3	4	4	4	5	5	6
Electricity in Specific Uses	87	92	99	105	110	114	116
Shares of Electricity							
Total	27	28	29	29	30	31	31
In Thermal Uses	1	1	2	2	2	2	2
Residential							
Total Final Energy	273	295	312	328	339	347	352
Total Electricity	60	67	76	85	95	104	110
Electricity in Thermal Uses	29	31	32	33	34	35	35
Electricity in Specific Uses	31	36	44	52	61	69	75
Shares of Electricity							
Total	22	23	24	26	28	30	31
In Thermal Uses	12	12	12	12	12	13	13
Tertiary							
Total Final Energy	159	174	189	201	213	221	227
Total Electricity	56	64	74	82	90	96	100
Electricity in Thermal Uses	28	32	34	35	36	38	39
Electricity in Specific Uses	28	33	40	47	53	58	61
Shares of Electricity							
Total	35	37	39	41	42	43	44
In Thermal Uses	21	23	23	23	23	23	23
Transport							
Total Final Energy	333	361	381	390	405	406	402
Total Electricity	6	6	7	7	6	6	6
Electricity in Motors	1	1	1	1	2	2	2
Electricity in Specific Uses	5	5	5	5	5	5	5
Shares of Electricity							
Total	2	2	2	2	2	2	2
In Motor Vehicles	0	0	0	0	0	0	0
All Sectors							
Total Final Energy	1095	1168	1238	1293	1341	1363	1374
Total Electricity	211	234	260	284	306	325	338
Electricity in Thermal Uses	61	68	72	74	77	80	81
Electricity in Specific Uses	150	166	188	209	228	245	257
Shares of Electricity							
Total	19	20	21	22	23	24	25
In Thermal Uses	6	7	7	7	7	7	7

Transport (Mtoe)	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total	273.2	294.8	333.0	360.6	381.1	390.3	405.4	406.0	402.2	396.5	390.8	363.9	338.8
Oil	267.9	288.8	326.1	349.3	361.2	364.9	374.4	371.7	366.5	357.5	348.5	318.0	289.4
Gas	0.2	0.3	0.3	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Electricity	5.1	5.5	5.9	6.4	6.8	6.7	6.4	6.3	6.2	7.6	9.0	9.2	9.5
Bio-fuels	0.0	0.2	0.6	4.1	12.4	17.6	23.0	25.6	27.2	28.8	30.4	33.2	36.1
New motor fuels	0.0	0.0	0.0	0.3	0.3	0.6	1.2	1.8	1.8	2.1	2.4	2.9	3.3

Table 26: "Efficiency & RES" Scenario – Electricity in Demand Sectors – EU25

Mtoe	2000	2005	2010	2015	2020	2025	2030
Industry							
Total Final Energy	330	339	350	357	359	362	362
Total Electricity	90	96	103	108	112	117	120
Electricity in Thermal Uses	3	4	4	4	5	5	5
Electricity in Specific Uses	87	92	99	103	108	112	115
Shares of Electricity							
Total	27	28	29	30	31	32	33
In Thermal Uses	1	1	2	2	2	2	2
Residential							
Total Final Energy	273	295	303	310	313	312	307
Total Electricity	60	67	75	83	90	94	96
Electricity in Thermal Uses	29	31	31	32	33	33	33
Electricity in Specific Uses	31	36	43	51	58	61	63
Shares of Electricity							
Total	22	23	25	27	29	30	31
In Thermal Uses	12	12	12	12	13	13	14
Tertiary							
Total Final Energy	159	174	180	185	189	188	181
Total Electricity	56	64	71	76	79	78	75
Electricity in Thermal Uses	28	32	32	33	33	34	34
Electricity in Specific Uses	28	33	38	43	45	44	40
Shares of Electricity							
Total	35	37	39	41	42	42	41
In Thermal Uses	21	23	23	23	23	24	24
Transport							
Total Final Energy	333	361	369	365	365	356	343
Total Electricity	6	6	7	6	6	6	6
Electricity in Motors	1	1	1	1	2	2	2
Electricity in Specific Uses	5	5	5	5	5	5	5
Shares of Electricity							
Total	2	2	2	2	2	2	2
In Motor Vehicles	0	0	0	0	0	0	0
All Sectors							
Total Final Energy	1095	1168	1203	1217	1226	1218	1193
Total Electricity	211	234	255	273	287	295	297
Electricity in Thermal Uses	61	68	69	71	72	74	75
Electricity in Specific Uses	150	166	186	202	215	221	222
Shares of Electricity							
Total	19	20	21	22	23	24	25
In Thermal Uses	6	7	7	7	7	7	8

Transport (Mtoe)	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total	273.2	294.8	333.0	360.6	369.2	364.7	365.2	356.1	342.6	322.6	303.8	274.3	247.6
Oil	267.9	288.8	326.1	349.3	348.9	337.2	329.3	313.9	293.2	271.0	249.9	216.2	185.4
Gas	0.2	0.3	0.3	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Electricity	5.1	5.5	5.9	6.4	6.7	6.5	6.2	6.1	6.1	6.5	6.9	6.5	6.1
Bio-fuels	0.0	0.2	0.6	4.1	13.0	20.0	28.0	34.3	41.5	42.5	43.5	47.4	51.3
New motor fuels	0.0	0.0	0.0	0.3	0.3	0.6	1.2	1.3	1.5	2.3	3.1	3.7	4.4

Table 27: "Supply Scenario" – Electricity in Demand Sectors – EU25

Mtoe	2000	2005	2010	2015	2020	2025	2030
Industry							
Total Final Energy	330	339	352	363	367	372	376
Total Electricity	90	96	103	110	116	121	124
Electricity in Thermal Uses	3	4	4	4	5	5	6
Electricity in Specific Uses	87	92	99	106	112	116	118
Shares of Electricity							
Total	27	28	29	30	32	33	33
In Thermal Uses	1	1	2	2	2	2	2
Residential							
Total Final Energy	273	295	307	319	324	332	338
Total Electricity	60	67	75	85	94	103	109
Electricity in Thermal Uses	29	31	32	33	34	34	34
Electricity in Specific Uses	31	36	43	52	61	69	74
Shares of Electricity							
Total	22	23	25	27	29	31	32
In Thermal Uses	12	12	12	12	13	13	13
Tertiary							
Total Final Energy	159	174	185	194	201	208	215
Total Electricity	56	64	73	80	86	91	95
Electricity in Thermal Uses	28	32	33	34	35	36	37
Electricity in Specific Uses	28	33	39	46	51	55	58
Shares of Electricity							
Total	35	37	39	41	43	44	44
In Thermal Uses	21	23	23	23	23	24	24
Transport							
Total Final Energy	333	361	378	383	394	396	395
Total Electricity	6	6	7	7	6	6	6
Electricity in Motors	1	1	1	1	2	2	2
Electricity in Specific Uses	5	5	5	5	5	5	4
Shares of Electricity							
Total	2	2	2	2	2	2	2
In Motor Vehicles	0	0	0	0	0	0	0
All Sectors							
Total Final Energy	1095	1168	1222	1258	1286	1308	1324
Total Electricity	211	234	258	281	303	321	334
Electricity in Thermal Uses	61	68	71	73	75	77	78
Electricity in Specific Uses	150	166	187	208	228	244	255
Shares of Electricity							
Total	19	20	21	22	24	25	25
In Thermal Uses	6	7	7	7	7	7	7

Transport (Mtoe)	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total	273.2	294.8	333.0	360.6	377.9	383.4	393.9	395.8	395.2	370.7	347.6	321.0	296.4
Oil	267.9	288.8	326.1	349.3	357.3	355.1	356.3	353.2	350.0	323.1	297.7	266.8	238.1
Gas	0.2	0.3	0.3	0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Electricity	5.1	5.5	5.9	6.4	6.7	6.6	6.3	6.2	6.0	6.6	7.1	7.0	6.9
Bio-fuels	0.0	0.2	0.6	4.1	13.1	20.7	29.8	34.5	37.2	38.1	38.9	42.4	45.9
New motor fuels	0.0	0.0	0.0	0.3	0.3	0.6	1.2	1.5	1.6	2.5	3.4	4.2	5.1

Table 28: "Role of Electricity" Scenario

Mtoe	2000	2005	2010	2015	2020	2025	2030
Industry							
Total Final Energy	330	339	351	358	360	362	367
Total Electricity	90	96	102	109	118	127	131
Electricity in Thermal Uses	3	4	4	6	10	16	18
Electricity in Specific Uses	87	92	98	103	108	111	113
Shares of Electricity							
Total	27	28	29	30	33	35	36
In Thermal Uses	1	1	2	2	4	6	7
Residential							
Total Final Energy	273	295	303	312	317	320	323
Total Electricity	60	67	75	86	99	119	137
Electricity in Thermal Uses	29	31	32	35	40	53	65
Electricity in Specific Uses	31	36	43	51	58	66	72
Shares of Electricity							
Total	22	23	25	28	31	37	43
In Thermal Uses	12	12	12	13	16	21	26
Tertiary							
Total Final Energy	159	174	180	187	193	197	202
Total Electricity	56	64	71	77	83	89	95
Electricity in Thermal Uses	28	32	33	34	36	40	43
Electricity in Specific Uses	28	33	38	44	47	49	51
Shares of Electricity							
Total	35	37	39	41	43	45	47
In Thermal Uses	21	23	23	24	24	27	29
Transport							
Total Final Energy	333	361	368	363	358	345	342
Total Electricity	6	6	7	10	17	31	39
Electricity in Motors	1	1	2	5	13	27	34
Electricity in Specific Uses	5	5	5	5	5	4	4
Shares of Electricity							
Total	2	2	2	3	5	9	11
In Motor Vehicles	0	0	1	1	4	8	10
All Sectors							
Total Final Energy	1095	1168	1203	1220	1227	1224	1234
Total Electricity	211	234	255	283	317	366	402
Electricity in Thermal Uses	61	68	70	80	98	135	161
Electricity in Specific Uses	150	166	185	203	218	231	241
Shares of Electricity							
Total	19	20	21	23	26	30	33
In Thermal Uses	6	7	7	8	10	14	16

Transport (Mtoe)	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total	273.2	294.8	333.0	360.6	368.5	362.9	357.7	345.3	342.1	317.7	295.0	268.4	244.2
Oil	267.9	288.8	326.1	349.3	347.7	332.7	314.1	287.5	277.5	249.0	222.2	192.7	165.6
Gas	0.2	0.3	0.3	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.2	0.2
Electricity	5.1	5.5	5.9	6.4	7.2	10.1	17.3	31.1	38.7	41.3	44.0	44.8	45.6
Bio-fuels	0.0	0.2	0.6	4.1	12.9	19.1	24.9	25.0	24.3	25.8	27.3	29.2	31.0
New motor fuels	0.0	0.0	0.0	0.3	0.3	0.6	1.1	1.2	1.2	1.3	1.3	1.6	1.8

Table 29: Baseline Scenario – Costs and Emissions – EU25

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total Cost of Energy (bln€'2005)	933	1055	1140	1240	1357	1466	1536	1566	1598	1638	1679
Total Cost per unit of Final Energy (€'2005/MWh)	73.2	77.7	79.2	82.5	87.1	92.5	96.1	98	100	103	105
Total Cost of Energy as % of GDP	10.4	10.9	10.4	10.1	9.9	9.8	9.6	9.3	9.1	9.0	8.8
Avg Cost of Power and Steam (€'2005/MWh)	36.5	39.0	39.7	39.9	40.6	42.2	43.8	44.7	45.6	46.7	47.9
Avg Fixed Cost (€'2005/MWh)	15.3	16.3	16.6	16.8	17.6	18.6	19.7	20.1	20.5	21.1	21.6
Avg Variable Cost (€'2005/MWh)	16.8	17.3	17.1	16.9	16.5	16.7	16.7	17.0	17.3	17.8	18.2
Cumulative Investment in Power (bln€'2005)	87	181	290	408	578	756	937	1147	1399	1645	1929
Avg Electricity Price (€'2005/MWh)	77.4	75.1	76.3	76.9	77.9	80.6	83.1	84.7	86.4	88.6	90.8
Industry (€'2005/MWh)	50.8	51.1	50.1	48.9	47.8	47.9	47.7	48.7	49.7	50.9	52.2
Residential (€'2005/MWh)	94.2	89.9	91.3	91.5	92.4	95.3	98.2	100.2	102.2	104.8	107.4
Tertiary (€'2005/MWh)	102.0	94.8	97.7	99.3	101.6	106.0	110.3	112.5	114.8	117.7	120.6

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
CO2 Emissions (Mt of CO2)	3776	3637	3674	3788	3886	3965	4077	4147	4172	4029	3891	3727	3569
Power Generation	1264	1203	1250	1291	1333	1373	1457	1560	1606	1603	1601	1578	1556
Rest of Supply	240	227	190	163	158	151	143	132	134	123	107	110	105
Industry	699	611	568	575	578	591	592	581	572	518	469	423	382
Domestic	780	740	697	719	744	763	770	766	767	760	753	751	749
Transport	793	856	970	1039	1075	1087	1115	1108	1092	1025	961	865	778
CO2 Emissions Index (1990=100)	100	96	97	100	103	105	108	110	110	107	103	99	95

Table 30: "Efficiency & RES" Scenario – Costs and Emissions – EU25

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total Cost of Energy (bln€'2005)	933	1055	1159	1281	1417	1541	1649	1650	1651	1689	1728
Total Cost per unit of Final Energy (€'2005/MW	73.2	77.7	82.9	90.6	99.4	108.8	118.8	119	119	122	125
Total Cost of Energy as % of GDP	10.4	10.9	10.6	10.4	10.4	10.3	10.3	9.9	9.6	9.4	9.3
Avg Cost of Power and Steam (€'2005/MWh)	36.5	39.0	39.7	41.2	43.4	45.9	48.3	48.3	48.4	49.5	50.6
Avg Fixed Cost (€'2005/MWh)	15.3	16.2	17.6	18.8	20.5	22.5	24.8	24.9	24.9	25.5	26.0
Avg Variable Cost (€'2005/MWh)	16.8	17.5	16.2	16.2	16.3	16.7	16.4	16.4	16.4	16.8	17.1
Cumulative Investment in Power (bln€'2005)	82	171	308	446	638	825	1030	1231	1473	1676	1842
Avg Electricity Price (€'2005/MWh)	77.4	75.1	76.2	78.6	82.3	87.0	91.4	91.5	91.5	93.6	95.8
Industry (€'2005/MWh)	50.8	51.1	49.7	49.6	50.3	51.9	53.1	53.1	53.1	54.3	55.6
Residential (€'2005/MWh)	94.2	89.9	91.8	94.5	99.2	105.8	112.8	112.8	112.9	115.5	118.2
Tertiary (€'2005/MWh)	102.0	94.8	98.3	102.6	109.0	117.4	126.6	126.7	126.8	129.7	132.7

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
CO2 Emissions (Mt of CO2)	3776	3637	3674	3792	3581	3304	3021	2838	2644	2487	2340	2101	1885
Power Generation	1264	1203	1250	1296	1133	935	745	663	583	560	537	515	494
Rest of Supply	240	227	190	163	149	135	117	105	97	96	91	82	67
Industry	699	611	568	574	550	534	496	473	454	403	357	290	235
Domestic	780	740	697	719	710	696	682	663	636	629	621	582	545
Transport	793	856	970	1039	1038	1004	980	935	873	800	734	632	544
CO2 Emissions Index (1990=10(	100	96	97	100	95	87	80	75	70	66	62	56	50
Emissions Captured	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 31: "Supply Scenario" – Costs and Emissions – EU25

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total Cost of Energy (bln€'2005)	933	1055	1176	1321	1502	1631	1704	1724	1745	1766	1786
Total Cost per unit of Final Energy (€'2005/MWh	73.2	77.7	82.8	90.3	100.4	107.2	110.7	112	113	115	116
Total Cost of Energy as % of GDP	10.4	10.9	10.7	10.7	11.0	10.9	10.6	10.3	10.0	9.8	9.6
Avg Cost of Power and Steam (€'2005/MWh)	36.5	39.0	39.9	41.5	45.8	49.9	51.5	52.1	52.8	53.4	54.0
Avg Fixed Cost (€'2005/MWh)	15.3	16.2	16.9	17.9	22.1	25.9	27.8	28.1	28.5	28.8	29.2
Avg Variable Cost (€'2005/MWh)	16.8	17.5	17.0	17.4	17.2	17.1	16.5	16.7	16.9	17.1	17.3
Cumulative Investment in Power (bln€'2005)	82	170	286	410	638	852	1026	1185	1358	1521	1753
Avg Electricity Price (€'2005/MWh)	77.4	75.1	76.5	79.0	87.0	95.8	99.3	100.5	101.7	102.9	104.2
Industry (€'2005/MWh)	50.8	51.1	50.2	50.1	52.6	56.3	56.5	57.2	57.9	58.6	59.3
Residential (€'2005/MWh)	94.2	89.9	91.7	94.5	104.2	114.7	119.1	120.5	122.0	123.4	124.8
Tertiary (€'2005/MWh)	102.0	94.8	98.3	102.7	115.3	127.9	133.7	135.4	137.0	138.6	140.2

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
CO_2 Emissions (Mt of CO_2)	3776	3637	3674	3794	3725	3466	3022	2776	2648	2445	2259	2066	1890
Power Generation	1264	1203	1250	1296	1226	987	591	381	274	215	169	114	77
Rest of Supply	240	227	190	164	156	150	135	120	115	128	130	146	145
Industry	699	611	568	575	558	551	529	514	503	454	410	369	331
Domestic	780	740	697	719	722	720	707	709	713	696	680	669	659
Transport	793	856	970	1039	1063	1057	1061	1052	1043	953	870	767	677
CO_2 Emissions Index (1990=100	100	96	97	100	99	92	80	74	70	65	60	55	50
Emissions Captured	0	0	0	0	0	0	215	513	671	738	805	738	671

Table 32: "Role of Electricity" Scenario – Costs and Emissions – EU25

	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Total Cost of Energy (bln€'2005)	933	1055	1156	1265	1385	1484	1547	1589	1632	1679	1728
Total Cost per unit of Final Energy (€'2005/MWh	73.2	77.7	82.7	89.2	97.1	104.3	107.8	111	114	117	120
Total Cost of Energy as % of GDP	10.4	10.9	10.6	10.3	10.1	9.9	9.6	9.4	9.2	9.1	9.0
Avg Cost of Power and Steam (€'2005/MWh)	36.5	39.0	39.6	40.5	42.6	47.0	49.2	50.5	51.9	53.4	54.9
Avg Fixed Cost (€'2005/MWh)	15.3	16.2	17.3	18.1	20.3	23.3	24.9	25.5	26.2	27.0	27.8
Avg Variable Cost (€'2005/MWh)	16.8	17.4	16.3	16.2	15.7	16.6	16.6	17.1	17.5	18.0	18.6
Cumulative Investment in Power (bln€'2005)	85	177	305	432	651	889	1102	1339	1667	2152	2909
Avg Electricity Price (€'2005/MWh)	77.4	75.1	76.2	77.2	79.7	87.0	90.0	92.5	95.0	97.7	100.5
Industry (€'2005/MWh)	50.8	51.1	49.7	48.7	48.4	51.5	51.7	53.1	54.6	56.2	57.8
Residential (€'2005/MWh)	94.2	89.9	91.5	92.1	94.7	102.4	105.0	107.9	110.8	114.0	117.3
Tertiary (€'2005/MWh)	102.0	94.8	98.1	100.2	105.2	114.9	119.6	122.8	126.2	129.8	133.5

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
CO_2 Emissions (Mt of CO_2)	3776	3637	3674	3793	3613	3379	3020	2745	2641	2452	2277	2073	1887
Power Generation	1264	1203	1250	1295	1172	1032	817	713	687	651	618	580	544
Rest of Supply	240	227	190	163	149	135	114	97	89	94	93	103	105
Industry	699	611	568	576	550	529	486	453	447	401	359	301	252
Domestic	780	740	697	719	707	692	668	626	591	576	561	529	499
Transport	793	856	970	1039	1034	990	934	856	826	730	645	560	486
CO_2 Emissions Index (1990=100)	100	96	97	100	96	89	80	73	70	65	60	55	50
Emissions Captured	0	0	0	0	0	0	62	404	587	713	839	829	818