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Long-term scenarios for strategic energy policy of the EU

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Table of Contents

Table of Figures and Tables

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1. Introduction

Formally the European Union member-states have no legal obligation to pursue a common energy policy and strategy. Each country may have different priorities and strategic choices. However, over the past ten years, two major policy developments, namely the climate change challenge and the establishment of a single Internal Energy Market, have brought the attention to the necessity of policy coordination and a common energy strategy in the European Union. These two policy domains are global, by nature, and have implications on the whole of the EU and its economic growth. Addressing these issues is neither efficient, nor possible, at the level of a single country.

This statement has been first reflected in the Green Paper on Security of Energy Supply, published by the European Commission in November 29, 2000, and has been further illustrated by the unprecedented policy-related debate and other policy reports that this document raised since its publication. The Green Paper and the related debate have shown that in the context of climate change constraints and the single internal market it is imperative to develop a common European strategic view on security of energy supply. This concept encapsulates both the delivery of affordable and sufficient energy by the competitive energy markets and the long term choice of energy demand and supply options that ensure sustainability, competitiveness and security.

The analysis has clearly shown that reducing carbon emissions from energy combustion implies higher operating and capital costs over a long transitory period. It is clearly more efficient in economic terms to do this by sharing the resources over the broader European scale. This optimises investment, reduces costs per unit of carbon avoided and removes the distortions that unilateral country-based actions would have on the European economy. The burden sharing agreement, at the EU Environment Council of the 16th of June 1998, and the emission trading directive, 2003/87/EC, reflect this necessity.

The establishment of a single EU energy market was imperative following the establishment of a single market for all commodities and services, the Single European Act in 1986 and the Maastricht Treaty in 1992. The liberalisation of the energy markets and the European wide competition in energy supply, that followed, have induced considerable implications on energy investment: raising debt and funding is taking place on a private basis and according to rigorous profitability and risk assessment criteria. Old policy practices led by strategic considerations and opting for capital intensive energy infrastructure, with long lead time and uncertain pay back, seem not possible under the present circumstances. Traditional policies, such as the state-owned energy companies carrying out strategic investment, the sovereign guarantees and the state-aids, are not possible in the new context. The only subsidy schemes allowed are those that relate to climate change objectives and concern renewable energies and the rational use of energy. Even those however are often criticised as distorting competition in the internal energy market.

Under the pressure of rising world-wide competition, the European Union felt the need to address, in a more comprehensive manner, the seemingly incompatible objectives regarding the environmental and economic competitiveness of the European industry. Achieving the former objectives would imply higher costs on the European industry that might cancel the expected benefits from energy market liberalisation. Moreover, the rising business risks associated with environment policies and the possible state interventions could even lead to displacement of investment away from Europe. This explains why in the Lisbon Agenda of March 2000, and the follow-up actions, the acceleration of technology progress was put forward as the only means for obtaining sustainable growth and competitiveness, hence reconciling the environmental with the economic competitiveness objectives. The objective of “strengthening competitiveness in industry and services through stepping up efforts in the areas of industrial policy, the services market and environmental technologies” gained a central place in all policy reports following the Lisbon Agenda (European Commission, 20.2.2004).

The above considerations explain why we talk now about a European energy policy and strategy and we seek for a European energy infrastructure and technological development.

The formation of such a common policy is difficult, given the complexity of the issues and the conflicting objectives. Energy policy in Europe is confronted with important decisions, which have long term consequences given the long lead times for energy investments and the long lifespan covering several decades. In preparing such decisions, it is important to have a comprehensive and consistent view on the various aspects of the economy that will be affected. For this purpose, energy systems and policy analysis on a European scale is required.

In view of this need, the European Commission supported a series of comprehensive analytical studies using energy systems modelling. Two such studies are the “Trends to 2030” and the “Scenarios on Key Drivers”, recently published by DG TREN (Fall 2004 and Winter 2005). Both studies use the results of the energy systems model PRIMES. Model based scenario analysis as presented in these publications provides a comprehensive and consistent view on future energy supply and demand including its driving forces. The present paper draws on these publications.

2. Energy trends under a baseline scenario

2.1. Assumptions

The baseline scenario quantifies the energy future arising from a continuation of current trends and policies in terms of economic, energy, transport and CO_2 trends over the period to 2030 for the enlarged EU of 25 Member States (called hereafter EU-25). This baseline also serves as the reference case against which the alternative scenarios representing alternative framework conditions and policies are assessed.

The Baseline scenario assumes that all current policies and those in the process of being implemented will continue in the future. However, the baseline scenario does not include additional policies to reduce greenhouse gases in view of the Kyoto commitments. In particular, no attempt has been made to forecast how Member States might endeavour to fulfil their Kyoto commitments. It is also assumed that EU-15 policies currently in place and in the pipeline will be gradually adopted and implemented by new Member States, according to each country’s rate of attainment of the ‘acquis communautaire’ and its overall path of convergence towards EU standards.

This approach allows the Baseline scenario to be considered as the benchmark against which a number of alternative policies can be assessed. The Baseline scenario takes into account:

a) technological progress, induced both by economic growth and by modernisation of installations in all sectors of the economy, thereby improving the efficiency of the energy system;

b) the restructuring of the sectoral pattern of economic growth, which gradually shifts away from traditional energy-intensive sectors and concentrates on high value added activities, thereby reducing energy intensity;

c) the effects from the restructuring of markets through the liberalisation of electricity and gas in the EU, which proceeds in line with the EC directives; liberalisation is assumed to be fully implemented before 2010; the completion of the internal electricity and gas markets is also assumed to progress in the new Member States;

d) the restructuring in power and steam generation, which is enabled by mature gas-based power generation technologies that are particularly efficient, involve low capital costs and are flexible regarding plant size, co-generation and independent power production;

e) changes in primary energy production patterns (especially in many new Member States), characterised by the closure of unprofitable coal mines that took place in the 1990s and which is expected to continue to some extent over the next few decades;

f) energy policies that aim at promoting renewable energy (wind, small hydro, solar energy, biomass and waste) and co-generation are assumed to continue, involving subsidies on capital costs and preferential electricity selling prices; rather than imposing the indicative targets of the EC renewables electricity Directive for each Member State, the baseline includes policy measures in view of higher renewables deployment in individual countries;

g) on going infrastructure projects involving the introduction of natural gas and the development of the gas supply market in a way that at least in the medium term there would be no major uncertainties with natural gas supplies; therefore low risk is associated with massive gas burning power plants;

h) differences in current policies of EU-25 Member States as regards nuclear capacity, taking into account policy decisions as regards nuclear phase out in Belgium, Germany and Sweden; and plans concerning nuclear plant refurbishment/closure, as already agreed or under negotiation with the European Commission for new Member States;

i) the effects arising from the voluntary agreement reached between the European Commission and the European automobile industry on specific CO_2 emissions from new cars (followed in 1999 by similar agreements with Korean and Japanese car manufacturers);

j) concerning the use of biofuels in transportation, it was assumed that all countries would follow EU rules; the impact of blending gasoline and diesel with biofuels on final consumer prices was assumed to be negligible, since higher fuel production costs will probably be offset by tax reductions scheduled to be implemented on these fuel blends.

k) finally, it is assumed that stringent regulation for acid rain pollutants continues, especially for large combustion plants; similarly, other clean air policies are assumed to continue.

2.2. Primary energy demand and supply in the baseline

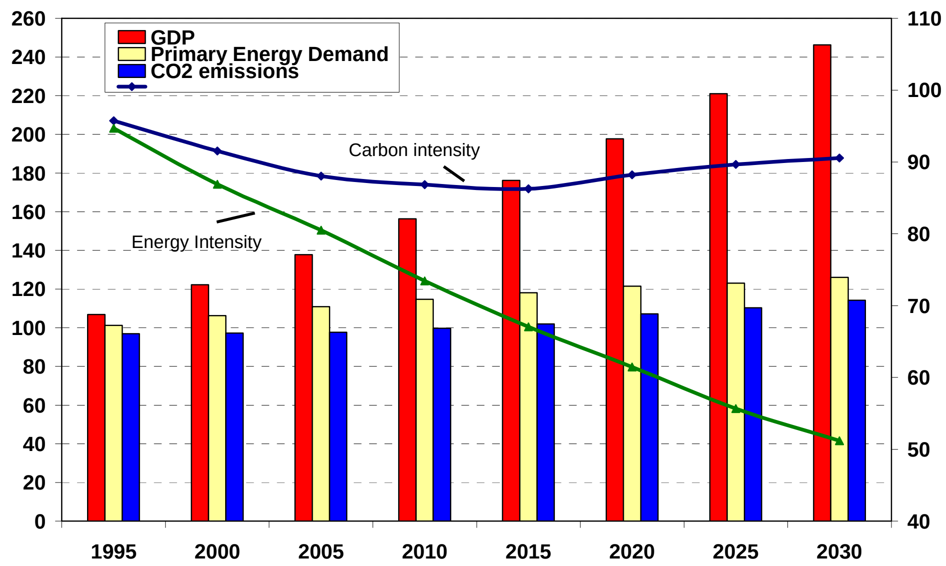
The results of the Baseline scenario show that, despite the evidence of relative saturation for certain energy uses in the EU-25, energy demand is expected to continue to grow, albeit at rates significantly lower than those experienced in the recent past. Primary energy demand in the EU-25 is projected to increase at an annual rate of 0.6% in 2000 to 2030 compared to an annual growth rate of 2.4% for GDP, implying that the energy intensity of the EU-25 energy system (expressed as primary energy demand per unit of GDP) will improve at a rate of 1.7% pa in 2000-2030. The evolution of the EU-25 energy system to 2030 under Baseline assumptions reflects a continuation of the decoupling between energy demand and economic growth. In 2030, one unit of GDP in EU-25 is expected to be produced with only approximately half the energy input that was needed in 1990. The main reasons that justify this significant gain in energy intensity under the Baseline scenario include improvements in energy efficiency (both on the demand and the supply sides), changes in the structure of EU industry, saturation in demand for some important energy needs, and the policies already in place under Baseline assumptions.

Between 1990 and 2000 CO_2 emissions in the EU-25 decreased by 2.8% whereas the corresponding primary energy needs grew by 6.2%, implying a significant improvement in the carbon intensity (-0.9% pa in 1990-2000) of the EU-25 energy system. The changes in the fuel mix during this decade were the key driver for this improvement. In the Baseline scenario CO_2 emissions are foreseen to grow throughout the projection period, but at lower rates than those for primary energy demand. In 2010, CO_2 emissions are projected to remain slightly below their level in 1990 (whereas the corresponding growth for primary energy needs reaches +14.8%). In 2030 CO_2 emissions exceed their 1990 level by 14.2% (+26.1% for primary energy demand). Nevertheless, the strong decoupling between EU-25 energy demand and CO_2 emissions, which occurred between 1990 and 2000, is not projected to continue in the long run whereas a worsening of carbon intensity is projected from 2015 onwards. Carbon intensity for the EU-25 energy system is projected to improve at a rate of -0.4% pa between 2000 and 2015. However, beyond 2015 the EU energy system is projected to become rather more carbon intensive (carbon intensity worsens at a rate of 0.3% pa). There are two main reasons for this result: (i) The opportunities for further CO_2 emissions reductions through fossil fuel switching are reduced, given that the technology possibilities and the economically attractive options are exploited mostly in the medium term; and (ii) Nuclear decommissioning in the EU energy system beyond 2015, combined with declared nuclear phase-out policies in certain EU Member States (namely Belgium, Germany and Sweden), generates a gap in power generation that cannot be satisfied fully by other carbon free fuels.

Table 1: Summary of baseline trends

Current Trends (baseline)					Annual growth rate	
EU - 25 MS	2000	2010	2020	2030	Short term	Long term
Primary Energy Needs (Mtoe)	1,651	1,784	1,889	1,960	0.8%	0.6%
Energy Intensity (to GDP)	185	156	131	109	-1.7%	-1.7%
Energy per capita (toe)	3.6	3.9	4.1	4.3	0.8%	0.6%
Share of renewables	5.8%	7.4%	8.0%	8.6%	5.1%	1.9%
Industry (Mtoe)	309	339	367	389	0.9%	0.8%
Buildings (Mtoe)	433	484	523	557	1.1%	0.8%
Transport (Mtoe)	332	387	427	449	1.5%	1.0%
Electricity use (TWh)	2,457	2,640	3,455	3,887	0.7%	1.5%
Gas in Power Gener. (bcm)	125	206	273	284	5.1%	2.8%
CO2 Index (1990=100)	97.2	99.7	107.2	114.2	0.3%	0.5%

Figure 1: Decoupling economic growth from energy needs and emissions under the baseline



Natural gas and renewable energy forms are projected to remain the fastest growing energy forms in the EU-25 energy system (as was the case during the last decade), growing at rates 3 times faster than overall energy needs over the projection period (+1.7% pa in 2000-2030 for natural gas; and +1.9% pa for renewable energy forms). Primary energy demand for liquid fuels exhibits moderate growth over the projection period (+0.2% pa) though at a rate well below average. However, although oil products are more and more used only in specific energy uses (transport and chemical), their share remain considerable reaching 34.4% in 2030 compared to 38.5% in 2000.

Solid fuels, after experiencing a strong decline in their share up to 2010, are projected to regain some market share in the EU-25 energy system beyond 2015 as a result of the increasing competitiveness of imported coal, the decommissioning of nuclear plants and the uncertainties associated with a further dash for gas in power generation. By 2030, primary energy demand for solid fuels is projected to come close to that observed in 2000.

Novel energy forms, such as hydrogen and methanol, are not projected to make significant inroads in the EU-25 energy system in the period to 2030 under Baseline conditions. In the Baseline, the EU-25 energy system is projected to become increasingly dependent on fossil fuels, though with significant changes occurring in the fuel mix. However, natural gas which is the less carbon intensive fossil fuel gains in terms of market share accounting by 2030 for 32.1% of primary energy needs (+9.3 percentage points compared to 2000 levels). This is mostly explained by the considerable expansion of the use of natural gas in power and steam generation.

Under the current trends and without considering the pressure from climate change objectives, nuclear energy is projected to account for only 9.5% of primary energy demand in 2030 (compared to 14.4% in 2000). Similarly, the share of renewable energy forms increases only moderately from 5.8% of primary energy demand in 2000 to reach 8.6% in 2030, which is below the declared objectives, despite the considerable support packages included in the baseline.

2.3. Growing import dependency

The combined effect of increasing primary energy demand for fossil fuels and declining primary production in the EU, results in a significant increase of import dependency for the EU-25 energy system from 47.2% in 2000 up to 67.3% in 2030.

Table 2: Primary energy supply trends in the baseline

EU-25	2000	2010	2020	2030
In Mtoe per year	level	Incremental change in a year compared to 2000		
Indigenous	**897**	**-37**	**-156**	**-236**
Solids	203	-50	-77	-101
Oil	164	-32	-61	-77
Natural Gas	197	0	-49	-80
Nuclear	238	8	-24	-52
Renewables	96	37	55	73
Imported	**797**	**175**	**405**	**562**
Solids	91	-2	35	106
Oil	520	53	106	131
Natural Gas	186	124	264	325

By 2030 some 88.3% of EU-25 oil demand will be satisfied by imports compared to 76.6% in 2000. Oil imports are projected to continue consisting mainly of crude oil, as net imports of oil products will remain marginal. The EU-25 external dependence in terms of natural gas is projected to increase sharply, reaching 81.4% by 2030 compared to 49.5% in 2000. As regards solid fuels, though import dependency under baseline assumptions is also projected to grow significantly, it remains at lower levels compared to oil and gas, reaching by 2030 65.8% - up from 30.1% in 2000. Both EU-15 and NMS energy systems are projected to reach similar levels of import dependency in the long run (67.8% and 63.6% respectively in 2030). This is despite the much better current position of new Member States, with an import dependency of 30.8% in 2000 compared to 49.4% in the EU-15. Faster growing energy needs in NMS, combined with a steep decline of indigenous solid fuels production, are the main reasons for this trend. The projected increasing dependency of the EU-25 energy system on energy imports (more than two thirds of primary energy needs in 2030) raises significant concerns as regards the security of supply in the long run. This is especially the case for natural gas given the increasing dependence upon gas imports from a limited number of suppliers and the need for long distance transport infrastructures, as well as the increasing natural gas demand in other world regions such as Asia. In the oil market, supply is increasingly concentrated in the Middle East while North Sea production declines. On the other hand, the world coal market remains well diversified with abundant supplies.

2.4. Energy in the final demand sectors

Final energy demand will continuously increase despite the shifts towards less energy-intensive manufacturing industries. Energy demand growth is explained by the rapid penetration of specific electricity uses, the growth of the services sector, the higher standards of living, associated with widespread ownership of private cars and domestic appliances, the increasing comfort levels in space heating and cooling and the increasing mobility of passengers and goods. As regards new Member States, the restructuring of Central and Eastern European countries' economies between 1990 and 2000, including the massive closure of old energy-inefficient factories and increasing energy prices progressively aligned to world energy market levels, explain the positive changes on the demand side. However in the longer term these countries are also projected to follow the trends shown for the old member-states.

Final energy demand in EU-25 is projected to increase by 29.8% between 2000 and 2030, well above that projected for primary energy needs (+18.7%). This difference reflects the significant efficiency gains in power generation expected under Baseline assumptions. Overall the final energy demand growth is rather similar in the EU-15 and NMS regions (+28.7% and +38.4% respectively in 2000-2030).

In the period 2000-2030, energy demand in EU-25 industry is projected to grow by 25.7% driven by higher activity in the presence of considerable energy intensity gains (+1.5% pa) which is due to structural changes towards less energy-intensive manufacturing processes. Energy demand in the tertiary sector is likely to continue growing at a rather uniform pace over the projection period (+1.2% pa in 2000-2030) in conjunction with the progressive restructuring of the EU-25 economy towards services. In the period to 2010, energy demand in households is projected to grow by 1.0% pa, but to decelerate afterwards to 0.6% pa in 2010-2020 and 0.3% pa in 2020-2030, as a result of saturation effects. The predominant role of the transport sector in final energy demand growth is projected to continue under Baseline assumptions. It is only in the long run that the combined effect of the decoupling of transport activity from economic growth (especially in passenger transport in EU-15) and technological progress leads to a deceleration of transport demand growth. However, the transport sector remains the fastest growing demand sector over the projection period and is expected to account for close to one third of final energy demand in 2030.

Electricity demand is projected to exhibit the highest growth over the period (+1.5% pa in 2000-2030). Electricity is the most valuable energy for the final demand sector given that electricity drives technological progress, comfort and economic competitiveness. This supports the view that sustainability and economic efficiency in the power sector plays 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.

Conversely, the demand for traditional fuels, such as solids and fuel oil is declining. Oil products are still massively used but for specific uses and mainly for transport. However the demand for natural gas increases (+1.1% pa in 2000-2030), but decelerates in the long run due to saturation effects. The exploitation of cogeneration opportunities leads to significant growth of demand for distributed steam (+1.4% pa) over the outlook period.

2.5. Electricity generation in the baseline

As mentioned above it is crucial for Europe to obtain affordable sufficient and high quality power supply. It is also crucial for climate change policy to obtain less carbon intensive power generation. The baseline projections show that from a strategic point of view competitive, clean and secure electricity is the most important policy challenge.

Under Baseline assumptions total electricity generation is projected to expand by 1.4% pa in 2000-2030. Despite this growth, electricity use per capita will remain rather low compared with US statistics. Electricity growth is faster in light industry, tertiary and households, implying higher peaking periods and a deterioration of the load pattern.

Increasing energy needs for electricity require large expansion of installed capacity in the EU-25 energy system, which is projected to almost double by 2030 from 2000 levels. Technological advances and the increase of competition in the electricity market - with smaller companies entering the market preferring plants with shorter lead times, lower capital costs and higher efficiency – explain the significant growth in the use of gas for electricity generation. This will take place mainly through the extensive use of gas turbine combined cycle units. Thus installed capacity of gas turbine combined cycle plants is projected to increase dramatically, especially in the period to 2020, reaching by 2030 close to 385 GW from 47 GW in 2000. Installed capacity of small gas turbines is also projected to grow by a factor of 3 over the outlook period. As a result, gas fuelled power plants will account for more than 40% of total EU-25 generating capacity in 2030 compared to 10.7% in 2000. The overwhelming growth of gas-fired power plants occurs mainly at the expense of conventional fossil fuel and nuclear power plants.

__Table 3: Power Generation capacities in baseline__

Power Generation Capacities in baseline	GW$_e$				
	1995	**2000**	**2010**	**2020**	**2030**
Nuclear	134.7	140.3	129.8	108.0	107.8
Large Hydro (pumping excl.)	91.2	94.1	95.8	95.9	96.3
Small hydro	2.0	2.1	8.9	13.4	15.9
Wind	2.5	12.8	72.7	103.5	134.9
Other renewables	0.0	0.2	0.5	0.6	14.2
Thermal plants	386.9	406.7	476.3	625.3	749.0
of which cogeneration plants	87.3	103.4	129.7	168.1	198.7
Open cycle - Fossil fuel	343.8	335.6	270.6	175.3	147.4
Clean Coal and Lignite	0.0	0.0	0.5	1.9	6.5
Supercritical Polyvalent	0.0	0.0	0.5	64.7	143.4
Gas Turbines Combined Cycle	20.4	47.4	169.6	318.8	384.6
Small Gas Turbines	22.0	22.8	33.9	63.3	65.8
Fuel Cells	0.0	0.0	0.0	0.0	0.0
Geothermal	0.7	1.0	1.2	1.3	1.4
Total EU-25	**617**	**656**	**784**	**947**	**1118**

Installed capacity of conventional thermal power plants (open cycle units) is projected to decline very rapidly both in absolute terms and as a share of total installed capacity. By 2030, they are projected to represent 17.8% of total installed capacity compared to more than 51% in 2000.

The nuclear sector faces four major issues: the closure of unsafe nuclear plants in NMS; the substantial decommissioning of existing nuclear plants beyond 2015 and mainly beyond 2020; the nuclear phase-out policies in certain EU-15 Member States; and the likely economic decisions not to replace all decommissioned nuclear with new nuclear plants. This explains the decline of nuclear capacity, which by 2030 accounts for no more than 9.6% of total installed capacity in EU-25 (from 21.4% in 2000).

In the longer term, it is likely that clean coal technologies gain in competitiveness and gradually become a choice for investment at a period when the natural gas expansion in power generation shall face saturation effects and probably supply uncertainties. Thus, by 2030 installed capacity of supercritical and other clean coal plants is projected to reach 143 GW (or 12.8% of total installed capacity).

Given supportive policies for renewable energy forms in the EU-15 - also likely to develop in new Member States - wind turbine capacity increases substantially, reaching by 2030 up to 135 GW (more than 12% of total installed capacity) compared to less than 13 GW in 2000. Solar photovoltaic energy starts emerging beyond 2020 (accounting for 1.3% of total installed capacity by 2030).

The strong shift towards a gas based power generation system combined with electricity market liberalisation is also projected to encourage the more widespread exploitation of cogeneration options, especially at the level of independent small-scale producers: from 103.4 GW in 2000 to 198.7 GW in 2030, so that by 2030, more than 16% of total EU-25 electricity generation will come from cogeneration units compared to 12.6% in 2000.

2.6. Carbon emissions in the baseline

The evolution of the EU-25 energy system in the last decade has been characterised by a strong decoupling of energy demand from economic growth and, in addition, by a decoupling between energy demand and CO_2 emissions growth. While primary energy needs increased by 6.2% in 1990-2000, CO_2 emissions declined in the same period by -2.8%. The restructuring of CEEC economies was the main driver for this trend (CO_2 emissions in NMS in 2000 were 20.4% lower than in 1990). In EU-15 structural shifts towards less energy intensive uses, technological progress and changes in the fuel mix all limited the CO_2 emissions growth to 1.2% between 1990 and 2000. As a result in 2000 new Member States' emissions accounted for 14.9% of overall CO_2 emissions at the EU-25 level compared to 18.2% in 1990.

CO_2 emissions, under Baseline assumptions, are projected to grow over the outlook period (+0.5% pa in 2000-2030). However, even in 2030, CO_2 emissions in NMS remain at levels significantly below those observed in 1990 (-7.6% lower) while emissions in the EU-15 are projected to rise by +19% from 1990 levels. In the period 2000-2010, CO_2 emissions for EU-25 are projected to grow by 2.5%, but still remain 0.3% below the level observed in 1990. The further changes in the fuel mix towards less carbon intensive fuels, on both the demand and supply sides, are the main reason for this limited growth, with emission reductions in industry and in district heating largely offsetting the emissions growth projected from the transport sector. Beyond 2010, CO_2 emissions are projected to rise much faster, with the power generation sector becoming the main driver for this increase. Massive decommissioning of nuclear power plants and increasing competitiveness of coal in the power sector cause these higher emissions. In contrast, the growth of CO_2 emissions in the transport sector decelerates in the long run both because of technological progress and as a result of the projected decoupling of transport activity from economic growth. This slowdown in transport emissions growth takes place in spite of modal shifts towards less energy efficient modes.

By 2030 electricity and steam generation account for 37.3% of total CO_2 emissions (from 32.6% in 2000) while the share of the transport sector reaches 29.2% (compared to 26.4% in 2000) - clearly reflecting the predominant role of these sectors in the EU-25 energy system. It is important to note that to the extent that final demand sectors, such as industry, services and households, switch to the use of more electricity they “export” considerable CO_2 emissions caused by their activities to the power generation and cogeneration sectors.

In the Baseline case the carbon intensity (CO_2 emissions per unit of primary energy needs) of the EU-25 energy system improves by no more than 1% between 2000 and 2030 Beyond 2015 carbon intensity worsens and CO_2 emissions rise accordingly to exceed in 2030 the 1990 level by 14%. Regarding the overall carbon emissions per unit of GDP, one should notice the considerably positive role of energy intensity gains leading to strong decoupling between CO_2 emissions growth and GDP growth. Energy intensity gains in 1990-2010 reach 27% and improve a further 30% in 2010-2030.

2.7. Policy implications under baseline assumptions

The EU-25 energy system will need to deal with a number of major challenges over the next 30 years, including issues related to security of supply, tightening environmental pressures, competitive energy prices and critical investment decisions. The integration of the new Member States in the EU is not projected to cause radical changes in the projected evolution of the EU-25 energy system in the period to 2030.

On the positive side, the further dematerialization of EU-25 industry, combined with structural changes within sectors, strong saturation effects for a number of energy uses, improvements in thermal characteristics of buildings in the tertiary and household sectors, the slowdown in transport activity growth and the impacts arising from the EU agreement with car manufacturers, all contribute towards the decoupling of energy demand from economic growth. Similarly, the improvements in energy technology, and changes in the fuel mix towards more efficient and cleaner energy forms, such as natural gas and renewables, also have a positive impact on energy intensity. In particular, the changes projected to occur in power generation towards the use of combined cycle plants and renewable energy forms further contribute to this positive evolution. The huge inefficiencies that prevailed in new Member States, and especially in CEEC, in the past and consequently the larger scope for efficiency gains compared to the EU-15, also act in favour of the decoupling between energy demand and economic growth in the EU-25.

On the negative side, the baseline scenario shows that the current trends and policies cannot deliver energy restructuring as needed for long term climate change policies. On the contrary, while in the short run the results are close to climate-related targets, in the long term the energy system evolution under current trends considerably deviates from the desired objectives in terms of carbon emissions. The limited success of renewables under current trends, the relative decline of nuclear energy and the re-emergence of coal, in the form of clean-coal power generation plants, explain this deviation.

The positive economic (low consumer prices and low capital requirements) and environmental effects of power generation expansion in the medium term, through the combined cycle plants, raise concerns about long term security of supply in Europe. The huge incremental quantities of natural gas concern the power generation sector on which the whole economy shall be depending, in terms of economic competitiveness and the well being of customers. However, this long term trend takes place together with the decline of primary energy production in Europe and the growing dependence on gas imports. In addition, the long term distribution of resources show that imports shall be increasingly depending on probably unstable areas, such as the Middle East.

Therefore, energy and transport policies will face considerable challenges in dealing in particular with security of energy supply and climate change issues that will become increasingly critical in the period close to 2030 for the EU-25 energy system.

3. Alternative Scenarios for the EU Energy Strategy

3.1. Assumptions

The analysis of the baseline scenario identified the need for additional policies and measures in particular with respect to implications on energy dependence and climate change. For this purpose, alternative energy scenarios are quantified.

Each alternative scenario combines several additional policy options. Three alternative scenarios were examined. The first focuses on energy policy options ("Energy policy options" case). The second ("Extended policy options") case addresses the combined effects of energy and transport policy options, as well as of the CO_2 emissions trading regime for the EU-25 energy system. Finally, the third case ("Full policy options") combines all policy options examined under the first two cases and further investigates the potential contribution of CO_2 sequestration from 2015 onwards in the EU-25 energy system. The key assumptions for the three cases examined are summarised below:

- The "Energy policy options" case examines the combined effects of promotional policies for renewable energy forms, better energy efficiency in all sectors and the availability and acceptance of new nuclear capacity. Regarding nuclear energy, the scenario assumes that new nuclear designs (such as the EPR or the AP1000 and AP600) with passive safety features become mature beyond 2010, allowing for improved public acceptance. For renewable energies, it is assumed that additional incentives are provided to energy consumers and producers so as to reach at least a 12% contribution from renewable energy sources to gross national energy consumption by 2010. Furthermore, measures promote the use of biomass and waste in industry, the use of solar thermal panels for water heating purposes in services and households and the use of biofuels in transport. For the supply side, it is assumed that additional support schemes are put in place promoting electricity generation from renewable energy forms. In addition the scenario assumes measures for higher energy performance of buildings, more efficient appliances and energy services such as heat, light, cooling, motion, etc. and the encouragement of the use of co-generated steam and electricity is encouraged.
- The "Extended policy options" case combines the above strong actions on energy efficiency and renewable energies with additional policies and measures for the sector of transport and economic instruments such as higher energy taxation and emission trading. Under this case it is assumed that the conditions favouring nuclear energy are not met, so nuclear energy remains close to the developments under baseline assumptions. For the transport sector a series of measures are assumed that increase the share of rail (both passenger and freight) and public road transport activity in delivering the overall transport volumes. In addition, the average load factors of all transport modes are assumed to increase and infrastructure is improved to facilitate the use of new fuels in transport vehicles, such as natural gas, biofuels and hydrogen to the horizon of 2020/30. The taxation of energy products and electricity is assumed to be harmonized and increased according to a full implementation of the taxation directive adopted in 2003. It is also assumed that greenhouse gas emissions allowance trading within the Community takes place as adopted in late 2003. The permit price for CO_2 emissions trading has been checked to in line with detailed analyses undertaken for the DG-Environment Clean Air for Europe program of the European Commission, which suggest that permit prices shall be formed in the order of 12 Euros per t of CO_2 in 2010, 16 Euros per t of CO_2 in 2015 and 20 Euros per t of CO_2 from 2020 onwards.

- The "Full policy options" case combines the policy measures considered for the above two scenarios and in addition it assumes that new technologies for power generation with CO_2 capture and sequestration will become available. It is also assumed under this case that the new nuclear technologies will become available and will be facilitated by improved public acceptance.

3.2. Results from the "Energy policy options" scenario

The combination of promotional policies for renewable energy forms, better energy efficiency in all sectors and the availability and acceptance of new nuclear technology leads to significant improvement of all energy efficiency indicators as regards the projected evolution of the EU-25 energy system in comparison to the Baseline scenario.

As a result of energy efficiency and higher prices, primary energy needs in the EU-25 almost stabilise over a thirty years period (average increase of 0.2% pa), showing a remarkable reduction from baseline levels. The changes from baseline on an annual basis reaches -5.9% in 2010 and -11.2% in 2030. The policies and measures assumed under this scenario result into a strong shift towards the use of nuclear energy (+34% in 2030 compared to Baseline) and renewable energies (+54% in 2010, +42% in 2030 over Baseline levels) which occur to the detriment of solids (-43% in 2030 compared to Baseline), gas and liquids (-21% and -13% respectively in 2030). The share of renewable energy forms is projected to reach 12.1% in 2010 (from 7.4% under the baseline), further increasing to 13.8% in 2030 (8.6% in the Baseline). The availability of new nuclear designs beyond 2010 leads to a significant boost in the use of nuclear energy in the long run, displacing both solid fuels and natural gas. The analysis did not find any conflict between the high penetration of nuclear and renewables simultaneously. On the contrary, their common development maximized benefits in terms of efficiency and carbon reduction. In the medium term, energy efficiency gains and the resulting decrease of energy needs dominate and explain the low penetration of new technologies. These however dominate developments over the longer term.

Table 4: Primary energy needs in "Energy policy options" scenario

	Mtoe				% change from baseline		
	2000	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
Solid Fuels	303	213	172	172	-12.7	-32.0	-42.7
Liquid Fuels	636	591	593	586	-9.6	-11.7	-13.1
Natural Gas	376	447	499	494	-11.8	-16.5	-21.4
Nuclear	238	222	227	248	-9.4	6.5	34.0
Renewable energy forms	96	204	227	241	53.8	49.9	42.2
Total	**1651**	**1679**	**1718**	**1741**	**-5.9**	**-9.1**	**-11.2**
EU-15	**1453**	**1487**	**1517**	**1546**	**-5.7**	**-8.5**	**-10.1**
NMS	**198**	**193**	**201**	**195**	**-7.4**	**-13.1**	**-19.0**

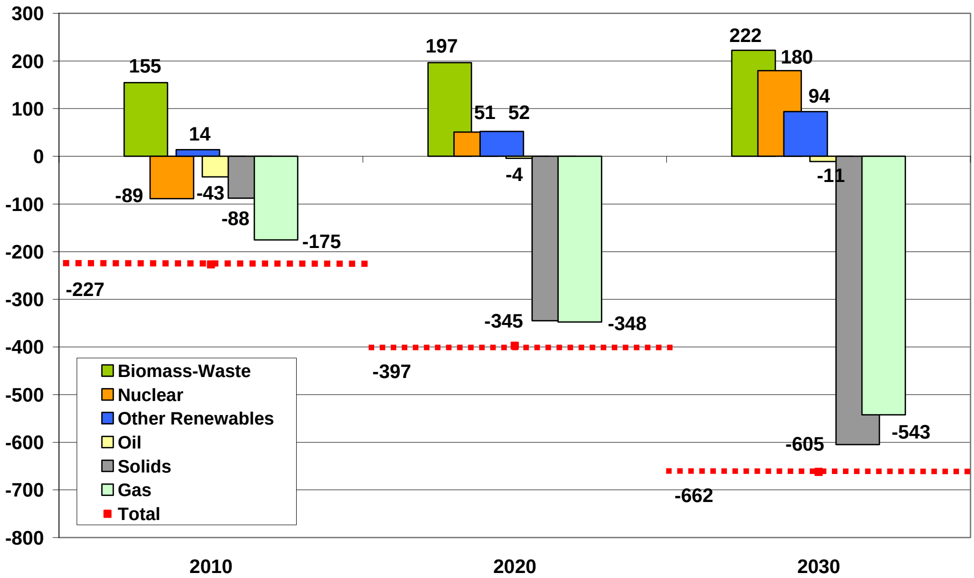
Import dependency is considerably less deteriorating than in the baseline scenario. The dependency ratio stabilises at a level of 55%, to be compared with 50% in 2000 and more than 65% in 2030 under the baseline scenario. However, dependence on imported gas remains a concern, but at a significantly lesser degree.

Table 5: Import dependency in "Energy policy options" scenario

	%				percentage points difference from baseline		
	2000	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
Solid fuels	30.1	34.5	39.1	56.0	-2.4	-10.9	-9.8
Liquid fuels	76.6	79.8	84.5	86.8	-1.5	-1.5	-1.5
Natural gas	49.5	57.1	70.3	76.0	-4.1	-5.1	-5.4
Total	**47.2**	**48.7**	**54.5**	**57.4**	**-4.4**	**-7.5**	**-10.0**
EU-15	**49.4**	**49.6**	**55.4**	**57.7**	**-4.7**	**-7.5**	**-10.1**
NMS	**30.8**	**41.6**	**47.1**	**54.6**	**-2.4**	**-7.6**	**-9.0**

Energy efficiency affects electricity demand which grows at an average annual rate of less than 1% over the thirty years period, instead of more than 1.5% in the baseline. Power generated in EU-25 is found to be significantly lower than in the baseline, as much as -6.6% in 2010 on an annual basis, and -15.1% in 2030. The structure of power generation is strongly influenced by the policies in favour of nuclear and renewables. Solid fuels and natural gas are displaced, mainly in the long term. In 2030, solid fuels account for 15.3% of total electricity generation (compared to 26.7% in the Baseline) and natural gas for 28.8% (from 36.8% in the Baseline). The share of zero-carbon fuels rises to 55.2% in 2030 compared with 35.6% in the Baseline. Electricity generation from nuclear in 2030 reaches levels above those observed in 2000 (+180 TWh or +23.5% from Baseline levels in 2030). The share of renewable energies in electricity generation is projected to reach 29.9% in 2030 (+11.7 percentage points above Baseline), and 24.1% of total electricity generation in 2010. Biomass and waste remain the key drivers as regards the growth of co-generated electricity, which in 2030 accounts for 27.5% of total electricity generation compared to only 16.3% in the Baseline.

Table 6: Changes in electricity generation in the EU-25 energy system in the "Energy policy options" case (diff. from Baseline in TWh)



Under the "Energy policy options" scenario, in 2030 the power sector needs in total 120 GW fewer power plants than in the baseline. This is a result of lower investment in gas plants (-150 GW) and coal plants (-135 MW), but higher investment in nuclear (50 GW), advanced thermal mainly for biomass with CHP (25 GW), wind (25 GW) and fuel cells (58 GW).

As a result of these changes in both supply and demand for energy, by 2030 total EU-25 CO_2 emissions are projected to be -25.2% below baseline levels (-11.9% in 2010). CO_2 emissions remain well below their 1990 level throughout the projection period: in 2010 CO_2 emissions are only 87.8% of those observed in 1990; in 2020 they are 86.4% of their 1990 level and 85.4% in 2030. The reduction of CO_2 emissions from the supply side (in 2010, -235 Mt CO_2 or -17.0%) is of equal importance to that achieved on the demand side over this period. The supply side achieves further CO_2 emission reductions in the long run, as a result of the accelerated penetration of carbon free technologies. CO_2 emissions reduction from the supply side reaches 749 Mt CO_2 (or -42.8% below the baseline levels in 2030).

3.3. Results from the "Extended policy options" scenario

The "Extended policy options" case corresponds to a zero-growth energy demand scenario. As a result of supportive policies for energy efficiency and the restructuring in the transport sector, total primary needs of EU-25 stabilise, even slightly decline, over the thirty years period.

The absence of a new "accepted" nuclear technology implies that nuclear energy gets a share similar to the baseline case. In absolute terms, nuclear energy is lower than in the baseline, since electricity demand is lower in the "Extended policy options" scenario. The policy package in favour of renewables explains the result, showing that primary renewable energy is more than 60% higher than in the baseline. The taxation and the emission trading explain the decline of solid fuels, while the measures restructuring the transport sector explain a considerable decrease in the use of petroleum products. Despite the stabilisation of the overall energy demand, the results show that natural gas needs are slightly lower than in the baseline, in particular in the longer term. This means that natural gas substitutes for other energy forms, such as solids and petroleum and emphasizes on the strategic role of natural gas in the context of the “Extended policy options” scenario.

This is a remarkable result showing that in the absence of new nuclear policy, the energy efficiency and renewables package is not sufficient to curb the long term dependency on natural gas, in particular if taxation and emission trading are oriented towards lower carbon emissions. This result is obtained despite the fact that the renewable energy forms are projected to grow at rates well above those observed under Baseline assumptions. Their market share reaches 13.1% of primary energy needs in 2010 (5.7 percentage points higher than baseline levels) and further increases to 16.2% in 2030 (7.5 percentage points higher than the baseline).

Table 7: Stabilisation of primary energy needs

	Mtoe				% change from baseline		
	2000	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
Solid Fuels	303.2	190.9	118.3	97.1	-21.7	-53.2	-67.6
Liquid Fuels	635.6	534.5	494.6	490.6	-18.2	-26.4	-27.3
Natural Gas	376.0	452.2	567.4	602.1	-10.8	-5.1	-4.2
Nuclear	237.7	223.1	191.7	160.8	-9.0	-10.2	-13.2
Renewable energy forms	96.1	212.5	242.2	260.8	60.2	60.1	53.9
Total	**1650.7**	**1615.4**	**1616.2**	**1613.7**	**-9.5**	**-14.4**	**-17.7**
EU-15	**1453**	**1429**	**1429**	**1432**	**-9.3**	**-13.7**	**-16.7**
NMS	**198**	**186**	**187**	**182**	**-10.7**	**-19.4**	**-24.5**

The stabilization of primary energy needs and the higher exploitation of renewable energy sources imply remarkable benefits in terms of import dependency which reaches 59.7% (7.6 percentage points lower than the Baseline). However, the removal of dependency mainly concerns the liquid fuels, while the concerns regarding import dependency on natural gas still hold true especially for the long run.

As a result of the transport policy package, passenger transport activity delivered by rail and public road transport show considerable increase above baseline levels (+20.5% and +11% respectively in 2010, +21% and +12.2% respectively in 2030). This occurs to the detriment of private road transport (-2.1% in 2010, -1.5% in 2030) and aviation (-10% in both 2010 and 2030). The market share of rail transport in passenger transport activity reaches 7.8% in 2010 and 7.6% in 2030 (from 6.4% and 6.3%, respectively, under Baseline assumptions).

Similarly in the freight transport sector, rail freight activity rises +23.9% above Baseline levels in 2030 (+22.2% in 2010). However, road remains the main freight transport mode despite a decline by 6% from Baseline levels in 2010 and 5% in 2030.

As a result of restructuring, energy demand for transportation is projected to drop in 2010 by 17.5% from baseline levels, 21.5% in 2020 and 21.1% in 2030, while the overall transportation activity remains unchanged from baseline. The analytical modeling provides detailed evidence about the contribution of each measure leading to such a substantial improvement of energy efficiency in transportation. The policy package includes measures that promote the shift away from petroleum-based engines and vehicles. This allows for a significant improvement of carbon intensity in the transport sector: CO_2 emissions from transport activity are projected to be -30.7% below baseline levels in 2030 (-22.5% in 2010), an improvement which exceeds the effects from energy efficiency gains.

In the power and steam sector, the “Extended policy options” case results into a considerable acceleration of the use of biomass-waste and other renewable energy forms in power generation. Thus, in 2010 electricity generation from biomass-waste (mainly in co-generation power plants) is 3.5 times higher than in the Baseline, further increasing to 4.4 times the Baseline level in 2030. Growth in the use of other renewable energy sources is also considerable (+4.4% from Baseline levels in 2010, +23.3% in 2030). The share of co-generated electricity is projected to reach 22.3% in 2010 and 25.8% in 2030 (from 14.4% and 16.3% respectively in the Baseline scenario).

Table 8: Transport sector restructuring

	Mtoe				% change from baseline		
	2000	**2010**	**2020**	**2030**	**2010**	**2020**	**2030**
road transport	273	273	282	292	-14.8	-19.5	-19.6
public road transport	7	7	7	6	0.2	-5.0	-3.1
motorcycles	2	2	2	2	-6.1	-9.0	-9.2
private cars	155	146	138	132	-12.6	-17.1	-17.2
trucks	109	118	135	152	-18.2	-22.5	-22.2
rail transport	9	8	6	7	-4.2	-0.8	5.8
aviation	45	33	40	47	-37.5	-37.4	-33.7
inland navigation	5	6	7	8	-1.2	-1.0	-0.2
Total transport	**332**	**320**	**335**	**354**	**-17.5**	**-21.5**	**-21.1**
EU15	**309**	**295**	**307**	**323**	**-17.4**	**-21.2**	**-20.6**
NMS	**23**	**25**	**28**	**31**	**-17.6**	**-25.2**	**-26.7**
Mt CO2 emitted	***969***	***861***	***840***	***872***	***-22.5***	***-30.7***	***-30.7***
EU-15	***904***	***795***	***768***	***796***	***-22.4***	***-30.5***	***-30.2***
NMS	***65***	***66***	***72***	***76***	***-22.7***	***-32.5***	***-35.1***

Power generation from coal and lignite is mostly affected in this scenario: the share of electricity generation from solids from 2020 onwards declines significantly reaching just 6.7% in 2030 (from 36.8% in the Baseline). Electricity generation from natural gas declines in absolute terms as a result of the reduction of electricity demand. The share of gas in electricity generation in 2030 remains at a very high level, close to 40% (+3.2 percentage points above Baseline levels). In the "Extended policy options" case the key driver for this trend in the long run is the strong penetration of fuel cell technologies in power generation (using natural gas reformed to hydrogen as input fuel). Indeed, in 2030, the installed capacity of fuel cells exceeds 105 GW, accounting for more than 10% of total installed capacity in the EU-25 power generation sector. Wind energy capacity also grows significantly above Baseline levels to reach 180 GW by 2030 (more than 18% of total installed capacity).

The restructuring of the transport sector, combined with renewables and energy efficiency under the "Extended policy options" case, lead to an important relaxation of environmental concerns of EU-25, as compared with the Baseline scenario. In 2010, total CO_2 emissions are limited to just 81.3% of those observed in 1990 (-903 Mt of CO_2 or -18.4% from Baseline levels in 2010), implying an "over-achievement" of Kyoto emission reduction targets. By 2030, CO_2 emissions are projected to further decline reaching a level corresponding to only 76.7% of total emissions in 1990 (-1413 Mt of CO_2 or -32.8% from Baseline levels). The reduction of carbon emissions can be equally attributed to demand and supply sectors but in the long run, the role of policy measures on the supply side is of increasing importance.

3.4. Results from the "Full policy options" scenario

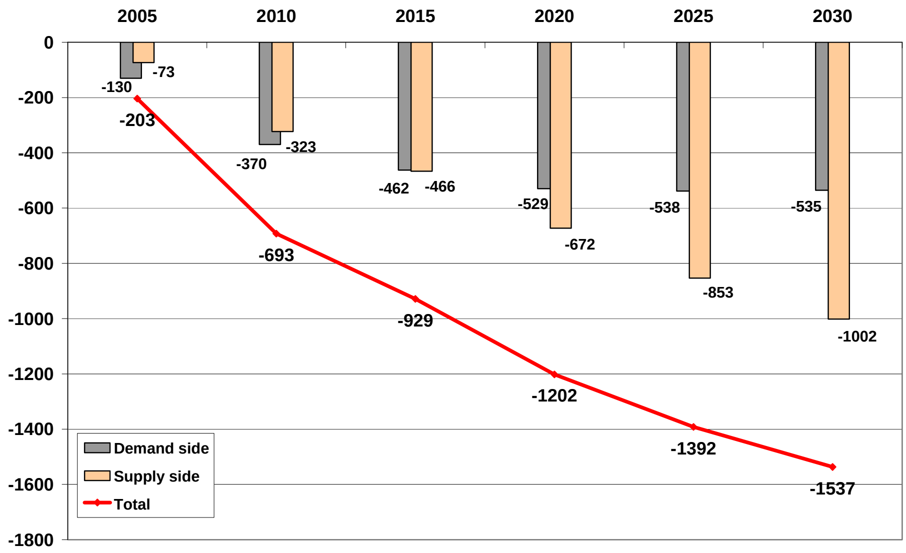
For the "Full policy options" case all policy options examined under the two cases presented above were combined, and the hypothesis of the availability of new nuclear technology was also included in the assumptions for this case. Furthermore, the potential contribution of carbon sequestration in power generation was examined by assuming that three advanced power plant technologies used by utilities (namely integrated gasification combined cycle power plants, supercritical thermal units and advanced natural gas combined cycle power plants) are - by default- equipped with CO_2 capture equipment from 2015 onwards.

This combined policy package stabilises energy demand over three decades and practically removes concern about import dependency. All final demand sectors exhibit high performance in terms of energy efficiency and the use of carbon free resources, including the transport sector in which considerable restructuring takes place. In power and steam generation, nuclear, renewables and fuel cells displace conventional technologies and significantly reduce dependency on solid fuels and natural gas in the long term.

This results into a considerable reduction in CO_2 emissions which is even more pronounced in the long run as CO_2 emissions in 2030 fall to only 73.4% of their Baseline level in 2030 (-1537 Mt of CO_2 or -35.7% from Baseline levels). The reduction is mostly attributed to the supply side (65%

of the total CO_2 emissions reduction), because of the faster penetration of renewable energy forms and the increased use of nuclear energy.

Figure 2: Changes in CO_2 emissions in EU-25 in the "Full policy options" case (diff. from Baseline in Mt CO_2)



If CO_2 capture and sequestration is considered as an obligation in the long term, the total cost of electricity would be charged with an additional amount of 12.1 billion Euro00 per year, in 2030, corresponding to an almost doubling of electricity pre-tax prices. This would result in a further reduction of CO_2 emissions of 134 Mt CO_2. Thus, in 2030 total CO_2 emissions in the EU-25 energy system would be limited to around 2632 Mt CO_2 (69.8% of CO_2 emissions observed in 1990 and -38.8% below Baseline levels in 2030). Carbon sequestration would entail a slight increase of primary energy needs (to power the sequestration process), with the reduction from Baseline levels in 2030 being limited to -13.7% compared to -14.1% in the "Full policy options" case (without sequestration).

With actual knowledge, it is clear from the analysis that the exploitation of CO_2 sequestration would be a costly option for the EU-25 energy system over the horizon up to 2030. It could, however, contribute to a significant reduction of CO_2 emissions if strong supporting policies are introduced.

4. Targeted carbon emissions scenarios

4.1. Assumptions

The repercussions of targeted CO_2 emissions reductions on the future evolution of the EU-25 energy system were examined by quantifying additional scenarios reflecting different CO_2 emissions reduction constraints over the projection period.

The energy consequences of the above CO_2 constraints that are compatible with Kyoto and possible post Kyoto targets were derived from treating the EU-25 energy system as one entity. The "targets" or emission constraints were achieved in modelling the energy economy in such a way as to obtain equal marginal costs across Member States and sectors, which ensures the lowest possible cost level in a given policy context.

4.2. Kyoto forever

The "Kyoto forever" case examines the achievement of a CO_2 emissions reduction of -5.5% from 1990 levels for the EU-25 energy system and a stabilisation of CO_2 emissions at these levels in the period to 2030. Given that under Baseline assumptions CO_2 emissions follow a growing trend, the gap between the Baseline and CO_2 emissions reduction target increases over time (from 196 Mt CO_2 or -5.2% in 2010 to 740 Mt or -17.2% in 2030).

The carbon values or marginal costs involved to reach the "target"98 rise from 15.3 €/t CO_2 in 2010 to 40.9 €/t CO_2 in 2030 (in prices of 2000). The energy system reacts to the introduction of CO_2 emissions constraints by improving energy intensity, and by improving carbon intensity through changes in the fuel mix towards the use of less carbon intensive or carbon free energy forms.

In the "Kyoto forever" case the response of the EU-25 energy system is dominated by improvements in terms of carbon intensity (accounting for 53% of overall CO_2 emissions reductions achieved in 2010, further rising to 67% in 2030). Primary energy needs decline by -2.5% from Baseline levels in 2010 and -5.7% in 2030. Changes in the fuel mix involve strong shifts away from the use of solid fuels, especially in the long run; in 2030 the demand for solid fuels is limited to 40.4% of that under baseline assumptions. Following the adoption of efficiency options in the transport sector, the demand for liquid fuels decreases (-4.9% in 2030).

Natural gas exhibits a limited decline in 2010 (-1.1% from baseline levels) but gains additional market share in the long run (growing by +5.0% above baseline levels in 2030) as it acts in replacing solid fuels in the power generation sector. Nuclear energy grows above baseline levels in the long run (+8.9% in 2030), which represents a significant increase taking into account that it has been assumed that Member States without nuclear and those with declared nuclear phase-out policies do not alter their approach to nuclear in this scenario.

Renewable energy forms become increasingly competitive in an environment of CO_2 emissions reduction constraints growing at rates well above those under baseline assumptions (+7.7% in 2010, +30.6% in 2030). The market share of renewables in primary energy needs reaches 8.2% in 2010 and 12.0% in 2030 (+3.3 percentage points above Baseline levels). The higher exploitation of indigenous energy sources in combination to the additional energy intensity gains occurring in the EU-25 energy system lead to a slower increase of import dependency which reaches 52.6% in 2010 and 64.2% in 2030 (-0.5 and -3.1 percentage points from Baseline levels).

4.3. Gothenburg type targets with domestic action

The "Gothenburg type targets with domestic action" case, examines the achievement of a -5.5% emissions reduction from 1990 levels in 2010 and the impact of the introduction of progressively higher emission reduction targets up to 2030. This follows the approach set out in the Commission's Communication in the run up to the Gothenburg Summit. This case partly reflects the stringent requirements for carbon emission reduction in compatibility with climate change targets.

Thus in 2020, the EU-25 energy system reduces its CO_2 emissions by -13% below the 1990 level, reaching -21% in 2030.

The imposition of higher CO_2 emissions reduction constraints in the long run leads to a higher exploitation of carbon intensity improvement options in the EU-25 energy system and implies the need for additional action in terms of improving energy efficiency. Thus, in 2030 energy intensity improvements account for 40.4% of the overall CO_2 emissions reduction achieved (compared to 33.3% in the "Kyoto forever" case).

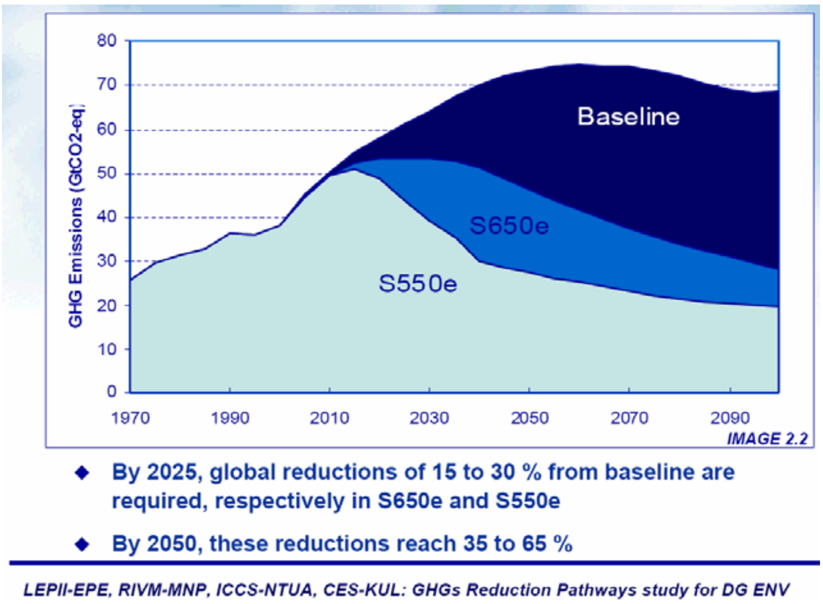
The need for additional effort towards improving energy efficiency, especially in the demand side, is also reflected on the carbon values or marginal costs, which reach 136.6 €'00 per t of CO_2 in 2030 in this scenario. This implies at least 50% higher electricity tariffs than today, in real terms.

The reduction of CO_2 emissions by -30.8% below baseline levels in 2030 (-21% from 1990) involves substantial changes in the EU-25 energy system. The energy intensity gains reach 12.4% as compared to baseline levels in 2030.

It is remarkable that in this context solid fuels are not used any more in the EU-25 energy system. On the other hand, there is substantial growth in the use of renewable energy forms (accounting for 15.5% of primary energy needs in 2030 compared to 8.6% in the baseline scenario). This leads to a decline in the share of fossil fuels in primary energy needs by 10 percentage points in 2030 from 81.6% in the Baseline to 71.8% in this scenario given the required deep cuts in CO_2

emissions, while import dependency also improves reaching 60.1% in 2030 (-7.2 percentage points below baseline levels).

Figure 3: Illustration of carbon emission reduction needed to comply with climate change targets



4.4. Other Gothenburg cases

Two additional cases were also examined, the "Gothenburg-flexible" case and the "Gothenburg-intermediate" case, reflecting the possibilities of achieving Kyoto type targets by other means than reducing energy related CO_2 emissions, i.e. in particular by using flexible mechanisms and by acting on other (non- CO_2) gases and sinks.

The results obtained from these two cases further confirm the findings discussed above with energy intensity improvements becoming increasingly important as higher targets need to be met.

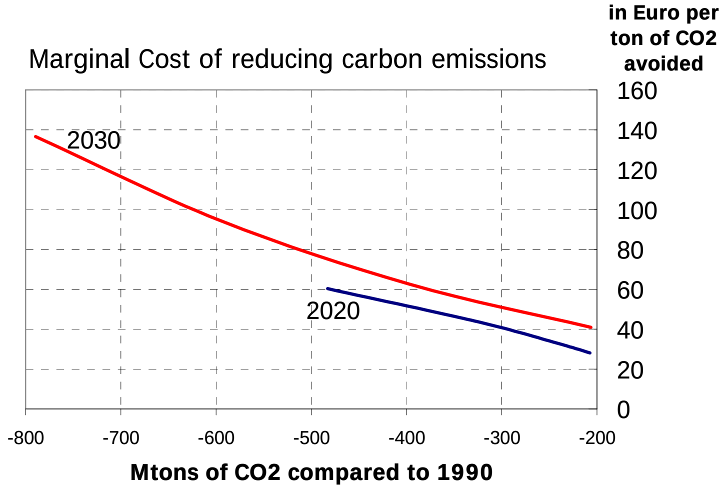
Figure 4: Summary of carbon oriented scenarios

	2000	2010	2030
Kyoto forever			
CO2 Emissions (Mt CO2)	3664.9	3561.2	3563.4
Reduction from baseline		-196	-740.2
% of 1990 level	97.2	94.5	94.5
Marginal Cost (Euro'00 / t of CO2)		15.3	40.9
Gothenburg with flexible mechanism			
CO2 Emissions (Mt CO2)	3664.9	3664	3373.3
Reduction from baseline		-93.2	-930.3
% of 1990 level	97.2	97.2	89.5
Marginal Cost (Euro'00 / t of CO2)		33	62.5
Gothenburg with domestic action			
CO2 Emissions (Mt CO2)	3664.9	2561.2	2980
Reduction from baseline		-196	-1323.7
% of 1990 level	97.2	87.2	79.1
Marginal Cost (Euro'00 / t of CO2)		15.3	136.3

Furthermore, the same analysis has been performed at the level of the EU-15 energy system. The results obtained clearly illustrate that it is much more difficult for the EU-15 energy system to meet CO_2 emissions reduction "targets" than for the EU-25. One reason is that higher emissions reductions from 1990 levels need to be achieved in EU-15 compared to EU-25 following the terms of the Kyoto Protocol. In addition the present characteristics of the EU-15 energy system in terms of both energy and carbon intensity are more advanced than those of the New Member States' energy system. Thus there exists bigger potential for low-cost improvements at the EU-25 level than for the EU-15. Third, the restructuring that took place in most of the New Member States during the 1990s led to a significant improvement of their position in terms of CO_2

emissions. In the EU-15 CO_2 emissions in 2000 were 1.2% above 1990 levels whereas in the NMS they were -20.4% below 1990 levels.

<u>Figure 5: Marginal Abatement Curve for EU-25</u>



5. Concluding remarks and policy issues

The results obtained from the various scenarios illustrate the large uncertainties that prevail as regards the future evolution of the EU-25 energy system to the horizon up to 2030. A variety of energy futures and key strategic choices are possible. The current trends, mainly driven by market forces hence seeking economic optimality, lead to an energy future which is not sustainable in the long term regarding long term security of supply and climate change impacts. The alternative energy futures that are possible involve additional investment funds and higher prices and costs during a rather long transitory period. The alternative energy futures involve restructuring in the demand side and accelerated technology development in the supply side. For both sides, the developments require acceleration of the replacement of energy capital and higher investment in new and improved technologies.

The choice of priorities regarding the sectors in the demand side and the technology-fuel promotions depend on the amplitude of the policy targets and constraints. The extreme case of restructuring corresponds to a policy target for deep cuts of carbon emissions in the post-Kyoto period. The implications in terms of higher prices and costs are considerable, but the benefits in terms of security of energy supply and technology progress are also remarkable.

It has been clearly illustrated that the amplitude of restructuring and the size of impacts associated with the three major policy objectives, namely economic competitiveness, protection of the environment and security of energy supply, call upon a European wide energy strategy. It was also made clear that the competition in the newly liberalized internal energy market of the EU could be highly affected, even distorted, by the amplitude of external costs and the possible state interventions that are associated with climate change mitigation targets.

In all cases the energy needs in the EU-25 are projected to exhibit a further de-linking from economic growth. Under Baseline assumptions energy intensity improvements of 1.7% pa in 2000-2030 are projected to occur in the EU-25 energy system. Even higher energy intensity gains are involved in the policy cases examined. Particularly strong policies towards improving energy efficiency are behind these developments. Such policies are difficult in their implementation, because unlike supply-oriented policies, they concern numerous and dispersed users of energy and affect the whole spectrum of economic and societal activities. Equally difficult policies are those needed to restructure the transport sector. It has been shown that such a restructuring of transportation may have tremendous benefits for energy policy and sustainability.

Under such a strong policy package in the demand side, it has been shown that energy demand could be even stabilized throughout the projection period. Energy intensity gains of a similar magnitude also occur in the presence of deep cuts of carbon emissions, such as in the

"Gothenburg type targets with domestic action" case, where efficiency gains reach the spectacular progress of 2.2% pa.

The analysis confirms the finding of many European Commission studies that import dependency will rise in the long term if current trends continue. In the baseline, the increase of import dependency will reach 67.3% in 2030, from 47.2% in 2000. A matter of concern is raised from the high volumes of natural gas to be imported over a long period and from rather unstable areas. This uncertainty, together with a decline of nuclear energy under current trends, explains the re-emergence of coal in the baseline future of the EU power system. Even if advanced clean coal technologies are used, such a trend will have serious adverse effects on carbon emissions in the post-Kyoto period.

All alternative energy futures involve lower import dependency in the long term, as compared with the baseline. A lower increase in import dependency occurs in the cases that involve more renewables and/or nuclear energy. A similar result is obtained with the extreme post-Kyoto scenario "Gothenburg type targets with domestic action". On the contrary, the abolishment of nuclear energy in the EU would entail larger security of supply concerns with import dependency in 2030 reaching 75% in the "nuclear phase-out" case. Promoting policies for renewables can only partly counterbalance this development as illustrated in the results of the "nuclear phase-out with strong support for renewables" case in which import dependency in 2030 reaches 71.1%.

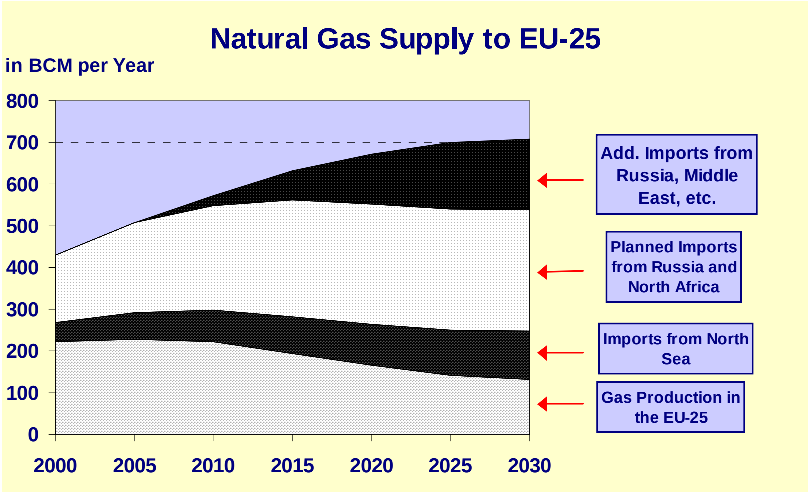
However, the key role of natural gas remains important in all cases. The uncertainties associated with long term supply of large volumes of natural gas are found in all the scenarios. Even in the case of large scale restructuring, for example with the emergence of fuel cells and despite the development of renewables and nuclear, the requirements for natural gas imports are significant and last for a long period of time.

The sensitivity analysis and the results from the scenarios on different policy cases show that the need for high natural gas imports is inelastic. The case involving the lowest requirements for natural gas imports still corresponds to a doubling of annual imports in 2030 compared to the year 2000. Independently of the uncertainty related to alternative energy futures, the European Union needs to plan for natural gas supply of the order of 630 to 680 bcm annually in the time period close to 2030. Gas production in the EU-25 and imports from the North Sea cannot exceed 250 bcm annually during the same period. Supply contracts that are known or anticipated and concern imports from Russia and North Africa are not more than 250 bcm per year. This implies an import gap of the order of 100 to 200 bcm annually. Security of gas supply being a critical factor for the EU energy futures, careful long term planning for new gas infrastructures is an imperative. New long distance gas pipelines (for example the routes from the South East of Europe), new LNG facilities and gas storage facilities should be delivered as a result of combined actions of the private sector, the market regulation and the EU wide supportive policies.

Table 9: Inelastic needs for natural gas imports

EU-25 Natural gas imports for each Scenario					
in bcm per year	**2000**	**2010**	**2020**	**2030**	**Index**
Scenarios					
Baseline	207	344	500	568	2.75
Low economic growth	207	324	467	511	2.47
High prices of oil and gas	207	313	444	467	2.26
Efficiency and renewables	207	283	400	444	2.15
Accelerated Nuclear	207	294	491	544	2.63
Strong Energy Policy	207	283	389	417	2.02
Extended Energy Policy	207	289	466	537	2.60
Full Energy Policy	207	289	448	510	2.47
Kyoto forever	207	339	521	602	2.91
Gothenburg climate targets	207	339	503	521	2.52
Average	207	310	463	512	2.48
Standard Deviation	0	25	44	56	0.27

__Figure 6: Gap in natural gas imports__



With import dependency increasing in all scenarios up to 2030 – albeit to a quite different degree according to each scenario – it is important to strengthen consumer– producer relations and energy partnerships. This should help ensuring secure and stable world energy market conditions. Moreover, mutually beneficial energy trade relations can exert a positive influence on geopolitical stability, which in turn exerts a positive influence on the security of energy supply.

As regards environmental concerns, the most favourable development in terms of CO_2 emissions and all other types of environmental impact occurs in the "full policy options" case, where CO_2 emissions exhibit a continuous decline over the projection period reaching -26.6% from 1990 levels in 2030 (or -30.2% if CO_2 sequestration is also taken into account). This is a substantial reduction considering that CO_2 emissions grow by +14.2% from 1990 in the Baseline scenario. Similarly, there are also deep cuts in CO_2 emissions in the "extended policy options" case (-23.3% in 1990-2030) and the "Gothenburg type targets with domestic action" case (-20.9% in 1990-2030). It is interesting to note that compared to the high costs involved in the achievement of the -20.9% reduction in the "Gothenburg type targets with domestic action" case, resulting from the introduction of carbon values that reach 136.6 €'00 per t of CO_2 in 2030, the adverse effects on energy system costs in the "full policy options" and the "extended policy options" cases are somehow lower. This result is due to the fact that in the two policy cases it is assumed that the member-states revise their current policies regarding the future contribution of nuclear energy and develop mechanisms supporting demand side efficiency and the deployment of new technologies, which gain economic efficiency through scale effects and learning by doing. All cases however involve considerable stranded costs and investment which are not often accounted for in the calculation of economic impacts.

This discussion illustrates that the energy sector, despite liberalization, will still require state-driven policies, regulation and intervention. The environmental targets correspond to high external costs that have to be internalized in the energy markets and the economic behaviour of both consumers and suppliers. Addressing the environmental issues largely depends on the development of new infrastructure which cannot be delivered solely by the free market, since the associated capital returns are very uncertain and since this infrastructure exhibits strong increasing returns to scale, which is due either to its nature as a network, or is due to strong learning-by-doing. For sure, such a state intervention will affect the competition in the EU energy market.

Nuclear is the energy source that is surrounded by the greatest uncertainty. In this analysis, the share of nuclear energy in 2030 spans a wide range from an extreme 0% (nuclear phase-out in the entire EU) to 16.4% in the scenario that combines all policy options including the acceptance of new nuclear technology. Note that the highest nuclear share so far was 14.8% in 2002 (the latest statistical year available). Under Baseline developments the nuclear share would fall to 9.5% in 2030. Nuclear capacity, from 140 GW in 2000, could go down to 100 GW in 2030 in the absence of new nuclear policy. Under most favourable conditions it could reach 175 GW in 2030. Under moderate nuclear policy, keeping the level of 140 GW combines well with other policy options, like renewables and energy efficiency improvement. A nuclear phase out would have considerable adverse effects on carbon emissions and import dependency. Extending nuclear lifetimes does not address the key strategic issue that arises beyond 2020. Absence of strategic choice about nuclear energy influences all investment decisions and renders impossible any consideration about nuclear investment by private entities. Keeping the nuclear option alive, even more attractive under market conditions, seems to be vital for the EU energy future, given also that it is unlikely that, up to 2030, accelerated renewables and/or hydrogen could equally perform in terms of costs, carbon emissions and import dependency. Note that the analysis clearly found that nuclear combined with accelerated renewables and energy efficiency deliver highest performance.

The combination of policies towards higher energy efficiency with promoting policies for renewables that ensures a 12% renewables share in 2010 leads to a 12% decline of CO_2 emissions below the 1990 level in 2010. Even though renewables policies are "frozen" at 2010 in this scenario, CO_2 emissions would remain broadly at 12% below the 1990 level up to 2030. Clearly, with reinforced renewables policies post 2010 even better results can be obtained and CO_2 emissions could fall further below the EU Kyoto commitments in 2008-2012 for the 6 greenhouse gases.

Although renewables exhibit a quite significant increase from 2000 to 2030, without additional policies on renewables addressing the period post 2010, market and technology developments alone entail only a limited increase of the contribution from renewables. To keep the momentum in terms of deployment of renewables technologies, the additional policies have to combine infrastructure facilitation (e.g. grid, distributed electricity, land use planning), subsidies, R&D and market-based instruments such as the green certificates.

The analysis shows that a policy package that combines extensive support for acceleration of renewables, standards and measures for high energy efficiency, advanced nuclear technology and new standards and fuels for transportation delivers high performance in all objectives, except regarding investment expenditures, stranded costs and higher energy prices. Carbon emissions can become significantly lower and attain a level in 2030 of -25% from 1990 level. One third of energy would come from carbon free sources in 2030. Import dependency would be restored to 55% in 2030, instead of 70% and more in the baseline. All indicators related to transport, air quality and congestion would show spectacular improvement. However, it would still need abundant and cheap gas supply: 2.5 times more than in 2000.

The European economy is comparatively strong in Equipment Goods Industry and the Services sector. The EU internal market area is also large and expanding. Under these conditions, a unilateral stringent policy in terms of energy-environment may drive accelerated technical progress and investment in the Equipment Industry and Services, resulting into economies of scale, hence in comparative advantage at world level. The EU-wide indigenous demand would sustain employment and activity in these sectors and facilitate economies of scale. Therefore, the obtained progress could in the longer term drive acceleration of economic growth of the EU supported by a new export potential by the energy, environmental equipment and related services sectors.

Such a strategy however needs a clear view to the future for the entire European Union, so as to reduce uncertainties that currently prevail and discourage private investment in large energy infrastructure and in new technologies. The removal of uncertainties and the design of supportive state interventions in compliance with the competition forces within the EU Internal Energy Market will also help the liberalized markets invest and take logical business risks. If such strategic choices are taken and confirmed at the EU level, it is likely that the European economy could enter into a new investment cycle, driven by energy-environment targets and the EU strong position in the technology of equipment goods.

The Green paper on the Security of Energy Supplies and the White paper on the Common Transport Policy have clearly shown that there are many challenges ahead to improve security of supply, the quality and the economics of the services to the users of energy and transport, and to alleviate impacts on the environment. Today's policy makers and citizens have it within their grasp to transform Europe's energy outlook to ensure sustainable development, including its economic, social and environmental dimensions.

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