Untying the energy knot of supply security, climate change, economic competitiveness:

The Role of Electricity

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The project described in this article is based on European conditions. The authors however believe that its relevance is much wider and that its basic conclusions can be significant for many if not all world regions. They are looking forward to further international complementary analysis, dialogue, cooperation and speedy action. A new energy policy "pathway" needs to be mapped out. The energy knot of supply security, climate change and economic competitiveness must be untied.

Abstract

In energy terms, the following decades will be dominated by the challenge of developing a low-carbon, energy-secure and competitive economy. EURELECTRIC launched a study, with as horizon 2030-2050, to develop a qualified vision about the role of electricity in responding to these challenges.

The resulting message is a positive one: with the right policies that include a long-term visibility of carbon pricing to allow integration of climate change impacts in investments and business strategies, it is possible to substantially reduce greenhouse gas emissions without unreasonable costs to the economy, and at the same time to reduce oil and gas dependency.

A focus on demand side energy-efficiency is a prerequisite. The development of renewables, of clean fossil fuel technology with carbon capture and storage, and of nuclear energy can make a low-carbon and largely oil-independent power generation mix a reality. This allows for formidable synergies with energy-efficient electro-technologies at the demand side. Two sectors are especially meaningful in this respect: the heating and cooling and road transport sectors, where heat pumps and plug-in hybrid cars respectively can make energy-efficient, oil-independent and low-carbon homes and cars a reality.

Although the analysis is based on European conditions, the authors believe that it has worldwide relevance.

1. Introduction

There is growing consensus worldwide that energy policies serving the current and future generations of citizens will need to respond to the triple challenge of drastically curbing greenhouse gas emissions, while continuing to ensure a secure energy supply, through solutions that are both economically feasible and provide prospects for economic growth and prosperity on a global scale, in particular for developing countries.

The quotes below give some indication of that consensus and what it really means for our planet.

"Energy prices have risen by an average of 15% in the European Union in the last year. 54% of Europe's energy is imported at a cost of €700 for every EU citizen. We have to address this urgently, by taking measures to increase our energy efficiency and reduce our dependence on imports. We have to invest and diversify. The proposals adopted today represent an unequivocal statement of the Commission's desire to guarantee secure and sustainable energy supplies, and should help us deliver on the crucial 20-20-20 climate change targets."

(EU President José Manuel Barroso presenting the Second Strategic Energy Review: "An EU Energy Security and Solidarity Action Plan" – 13 November 2008)

"The EU has come together as never before to deal with climate change, high energy prices and energy security. But we have to do more, be more ambitious, and be even bolder to avoid the risk of energy disruption in the future. This means investment. Investing in energy, including energy efficiency, means giving our economy the push it needs at this uncertain time."

(EU Energy Commissioner Andris Piebalgs presenting the Second Strategic Energy Review: "An EU Energy Security and Solidarity Action Plan" – 13 November 2008)

"Global energy demands are expected to grow by 60% over the next 25 years. This has the potential to cause a significant increase in greenhouse gas emissions associated with climate change."

"Secure, reliable and affordable energy sources are fundamental to economic stability and development. Rising energy demand poses a challenge to energy security given increased reliance on global energy markets."

(Climate Change, Clean Energy and Sustainable Development, G8 Gleneagles – July 2005)

"The world's energy system is at a crossroads. Current global trends in energy supply and consumption are patently unsustainable - environmentally, economically, social. But that can - and must - be altered; there's still time to change the road we're on."

"It is not an exaggeration to claim that the future of human prosperity depends on how successfully we tackle the two central energy challenges facing us today: securing the supply of reliable and affordable energy; and effecting a rapid transformation to a low-carbon, efficient and environmentally benign system of energy supply. What is needed is nothing short of an energy revolution."

"[...] The sources of oil to meet rising demand, the cost of producing it and the prices that consumers will need to pay for it are extremely uncertain, perhaps more than ever."

(World Energy Outlook 2008 - International Energy Agency)

"The future energy policy has to focus on the three aspects of sustainability. (…) In terms of concrete action, this translates into energy policy being driven by a threefold objective: competitiveness, environment (within which combating climate change is a priority), and security of supply. Any energy-related measure or proposal has to be benchmarked against this threefold objective to ensure coherence."

(Second Report of the EU High Level group on Competitiveness, Energy and the Environment, 30 October 2006)

"There is still time to avoid the worst impacts of climate change, if we take strong action now."

"The scientific evidence is now overwhelming: climate change is a serious global threat, and it demands an urgent global response."

"The investment that takes place in the next 10-20 years will have a profound effect on the climate in the second half of this century and in the next. Our actions now and over the coming decades could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes."

(Stern Review: The Economics of Climate Change, October 2006)

1.1. What role for electricity in providing secure and competitive energy in a carbon constrained world?

The electricity industry, in particular in the industrialised world, must play an important, pro-active role in providing economically feasible solutions for ensuring security of supply and achieving reductions in greenhouse gas emissions.

"Industry leaders believe that electricity can be the solution to climate change. Developed economies must lead and are committed to share technologies and experience to allow the developing economies to follow …. with aggressive application of technology, carbon emissions reductions of 60 to 80 percent can be achieved by 2050.

[…] considering the role of electricity in improving standards of living, potential electrification in society as a whole should be continuously explored while promoting energy savings and consequently reducing greenhouse gas emissions in every sector."

Declaration from the International Electricity Chief Executives Summit
(US, Canadian, European, Japanese and Australian associations)
Atlanta, Georgia, 6-7 October 2008

"Recognising that climate change is a serious global environmental, economic and social challenge which requires urgent action [...] Our companies are developing innovative ways to inform customers on energy-efficient solutions and to encourage the use of electricity where it contributes to reducing emissions of GHGs. In particular, we will invest or promote investment in the necessary infrastructure to foster the development of electric vehicles, including support for the standardisation necessary for their deployment. We will also encourage energy efficiency for sustainable cities."

Declaration by European Electricity Sector Chief Executives on
Climate Change, Electricity Markets and Supply Security – Brussels, 18 March 2009

The European electricity industry, through its representative body, EURELECTRIC, launched a project on the *Role of Electricity*. The project covers the time horizon to 2050, which is consistent with the long lifetimes of many energy-related investments and thus relevant for both policy-making and industry decisions being taken today. The purpose of the project is to draw up an authoritative view on the future role of electricity in relation to the triple challenge of climate change, security of supply - in particular regarding oil and gas dependency - and economic competitiveness.

Key questions are:

- What existing or new energy-efficient demand-side technologies can play a key role during the coming decades and what will be their impact?
- What existing or new low-carbon energy and electricity supply technologies can play a key role during the next decades and what will be their impact?
- What are the benefits of a balanced energy policy, based on actively developing and deploying all low-carbon demand and supply options - energy efficiency, renewables, clean fossil fuel with carbon capture and storage, and nuclear energy?
- What are the synergies between, on the one hand, the transition to low-carbon electricity supply and, on the other hand, the expansion of efficient electro-technologies on the demand side, in particular in the transport and heating & cooling sectors?
- What conclusions can be drawn with regard to the future role of electricity?
- What policy recommendations emerge from this analysis?

The project covered the European Union of 25 Member States, as in 2006. Obviously, the project has a much wider relevance and is also meant to contribute to the worldwide debate on reorientation of energy policies.

1.2. General project organisation and final report

The work was undertaken in three work blocks: a) future development of energy demand and electro-technologies, b) future development of electricity supply technologies and c) energy modelling. EURELECTRIC worked in close cooperation with a number of partners whose expertise and close involvement made the project possible, each partner focusing on a specific domain:

- For demand side aspects: a consortium led by Professor Belmans and Professor Van Reusel of the University of Leuven, together with the

University of Coimbra, the University of Toulouse, LABORELEC and the University of Bayreuth

- For supply side aspects: VGB Powertech (Dr. Bauer)
- For modelling: E3MLab of National Technical University of Athens (Professor P. Capros)
- For general advice: McKinsey & Company.

Interested readers are advised to consult *www.eurelectric.org* *to obtain the final report and access to more detailed information.*

2. Demand side aspects

A prospective investigation was carried out with regard to demand side developments, and to the impact of existing and new technologies in different areas of the European economy. The analysis aimed at providing quantitative elements as much as possible, horizon 2030, and a more qualitative analysis, horizon 2050. The different sectors, and the most important technologies and applications within those sectors, were thoroughly investigated. A potential for significant energy-efficiency improvements was identified in nearly all cases. These findings provided input to complement the PRIMES economic model used for scenario analysis.

An overview of the energy demand and of the electricity demand in EU-25 is given in the table below. The prospective figures for 2030 are taken from the PRIMES-model baseline calculations. Baseline calculations represent the natural evolution of demand while continuing present energy policies.

	Energy Use (MToe)		**Electricity Use (TWh)**	
	2005	2030	2005	2030
Industry	339	393	1111	1413
Residential	295	352	784	1281
Tertiary (service sectors)	174	227	748	1163
Transport	361	402	75	72
TOTAL	**1168**	**1374**	**2718**	**3929**

(source: PRIMES baseline EU-25)

By 2030, under baseline conditions, Transport would be the largest energy consumer, while growth will be largest in the Tertiary sector (+1% per year). Industry would still be the major user of electricity, while growth in electricity demand would be mainly in the Residential and in the Tertiary sectors (+1.9% per year).

Energy efficiency improvements will be an important goal in all energy applications but they will be paramount in the Transport sector, which is not only the major user of energy, but also relies overwhelmingly on imported oil as its energy source. To a significant extent, the same consideration holds space heating, relying on imported gas and oil. In the Residential and Tertiary sectors, many specific electricity applications – heating, cooling, household appliances, lighting and standby power – can be targeted for efficiency improvement.

Of particular relevance are two electro-technologies that have the potential to greatly improve energy efficiency, reduce oil and gas dependency, and curb CO_2 emissions - in the heating and cooling, and in the road transport sectors respectively. Both sectors are very important because of their substantial share in total energy use and their large or almost complete dependency on oil and gas.

Heat pumps, by extracting ambient renewable heat or cold, can indeed condition buildings significantly more efficiently than conventional direct combustion of oil or gas. In combination with low carbon electricity mix a synergy can be developed to substantially reduce CO_2 emissions for heating and cooling. Heat pumps are already widely applied in some countries (e.g. Sweden, Switzerland) and their use can be expanded under economically attractive conditions.

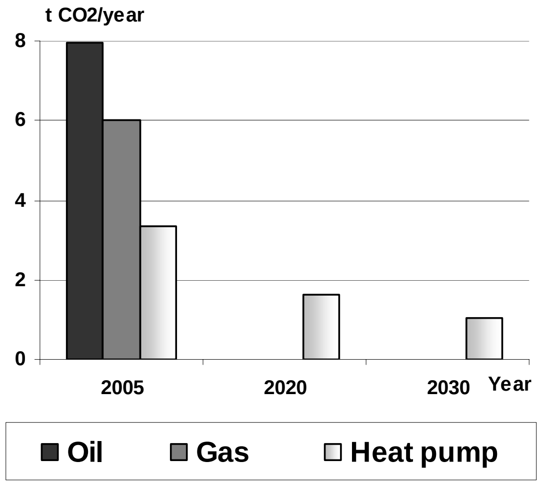
The plug-in hybrid vehicle (PHEV) provides the possibility to substantially reduce CO_2 emissions and improve the energy efficiency of road transport, and to reduce its oil dependency without sacrificing the comfort and safety demands of passengers. The PHEV is a logical further development of the hybrid car, which is already now becoming part of the market. It has a larger battery which is loaded as much as possible by the electricity grid, instead of by the motor engine, allowing use of grid electricity for typical city and commuting drives and limiting the need to revert to oil for longer distance drives. Again, in combination with a low carbon electricity mix, a synergy can be put to work to significantly reduce both CO_2 emissions and oil use.

The PHEV can gain substantial market share as of 2020.

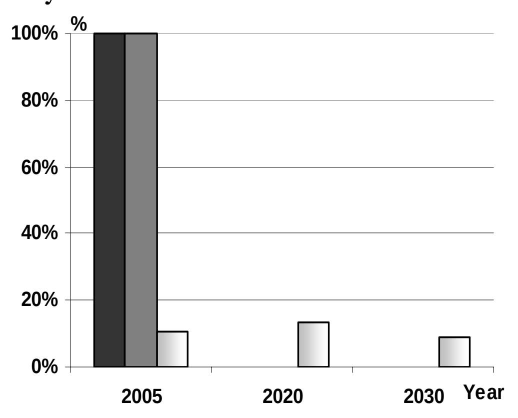
Figures 1a&b and 2a&b illustrate the dramatic decreases in both CO_2 emissions and oil/gas dependency that are enabled by heat pumps and by PHEV's in combination with a low-carbon electricity supply. The electricity supply in the figures corresponds to the "Role of Electricity" scenario detailed in Chapter 4.

<u>Figures 1a and 1b</u>: Spatial heating - impact of heat pumps

CO_2-emissions

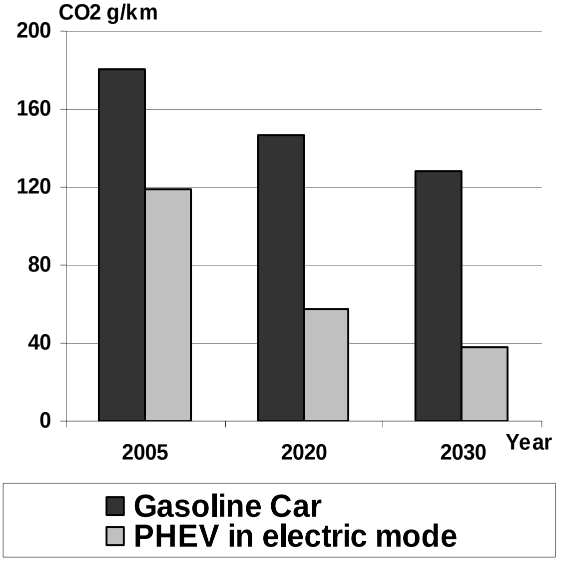


Oil/gas dependency

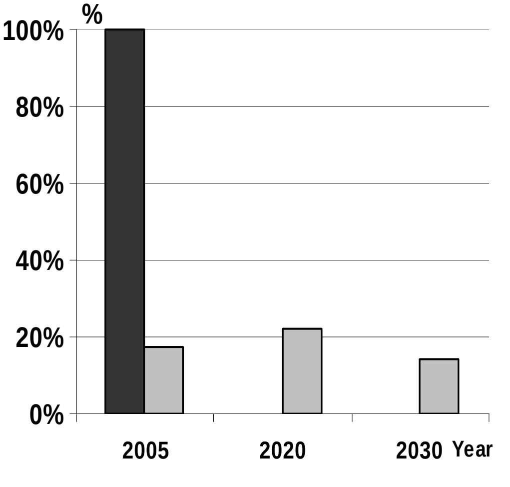


Figures 2a and 2b: Road transport - impact of PHEV's in electric mode

CO_2-emissions



Oil/gas dependency



3. Supply side aspects

A prospective analysis was carried out with regard to different electricity generation technologies:

- Fossil fuels fired power plants, either with or without carbon capture technology: steam cycle hard coal and lignite power plants; Integrated Gasification Combined Cycle (IGCC), Oxyfuel Power Plant, Gas Fired Power Plant Combined Cycle.
- Renewables, including on-shore and off-shore wind energy; various types of hydro power plants i.e. run-of-river, pumped storage and storage, biomass power plants, solar thermal and photovoltaic and geothermal.
- Nuclear power plants: light water reactors, fast breeder reactors, high temperature reactors.
- Small scale generation: fuel cells, micro gas turbines, Stirling engines and internal combustion engines.

For each technology an estimate was made, horizon 2030 and 2050, of key investment, operation and energy efficiency parameters, as input to the economic model used for scenario analysis.

Nuclear fusion and large-scale use of hydrogen are developments with a very important potential impact, but have time horizons outside the scope of this study.

Carbon capture and storage is an emerging technology that allows combining the use of fossil fuels for large-scale electricity generation with low CO_2 emissions. With necessary R&D and demonstration efforts, the technology is expected to become available for commercial use after 2020. Energy efficiency losses are expected to decline substantially over time.

The European Commission, in its January 2007 Strategic Energy Review - "An Energy Policy for Europe" - and its follow-up, second Strategic Energy Review in November 2008 – "An EU Energy Security and Solidarity Action Plan" - underlines and confirms the establishment of a favourable regulatory framework, the incorporation of CO_2 capture and storage in the Emissions Trading System, and the construction and operation by 2015 of up to 12 large-scale demonstration plants in commercial power generation. The European Commission believes, on the basis of existing information, that after 2020 all new coal-fired plants should be fitted with CO_2 capture and storage, and existing plants progressively retrofitted.[1]

Although setting the timescale for mandatory policies may seem premature before real industrial demonstration, the project's analysis confirms that carbon capture and storage is indeed a key technology development holding the promise of further use of coal with low CO_2 emissions beyond 2020.

The analysis demonstrates that, under the right policy framework, the transition to a low carbon power generation mix is technically and economically feasible.

4. Energy Modelling and scenarios[2]

4.1. 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 project partners used the PRIMES energy system model for detailed projections up to 2030 and the Prometheus world energy model for a 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 project, applying a bottom-up approach. These teams provided technical and economic

[1] See http://ec.europa.eu/environment/climat/ccs/pdf/primes.pdf for detailed impact assessment.
[2] This is a collective work involving P. Capros, L. Mantzos, N. Kouvaritakis, V. Panos, V. Papandreou and J-F Guilmot.

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.

The *models* represent multiple economic sectors and multiple energy forms, commodities and market. 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 as given the world fossil-fuel prices and focuses 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 use. Policy instruments for emissions-limitation are also represented, including emissions caps, taxes and trading of emission allowances. Similarly, a series of energy-related policy instruments is represented, including on 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 policies and changes that are reflected in the alternative scenarios.

4.2. Baseline Scenario

The Baseline scenario, which reflects business-as-usual trends, is very similar to that used in the last update of the European Commission Energy and Transport "Scenarios on key drivers" (2006). Dynamic trends and changes are reflected, but their evolution is assumed in this scenario to result only from existing (*i.e.* pre-2004) policies and trends, without any consideration of new policy instruments or policy targets. It is **not a forecast**, but a simulation of what the limitations of the system would be if it simply continued to evolve without reacting to perceived failures or adverse effects. Hence, Baseline assumes that the current EU Emissions Trading System (ETS) continues to operate, inducing 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, but it does not assume any further measures that the European Union might enact in order to reduce emissions of greenhouse gases in pursuit of the Kyoto climate change targets, pre- or post-2012.

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, Baseline only takes account of policies, standards and measures already in place.

Energy efficiency and productivity gains under Baseline are driven by the aim of minimizing costs and maximizing economic growth without any consideration of externalities such as the impact on climate change or of possible risks and threats to long-term energy supply security. Similarly, renewables, given the supportive policies which continue under Baseline but are not expanded, see further development as a result of market forces and the drive for least-cost supply. In fact, under this scenario, energy efficiency shows remarkable progress if we compare Baseline with the projected energy demand in a situation where energy intensity remained frozen.

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. Worldwide economic activity is projected to grow steadily at a rate of 3% per year until 2030 and by 2.2% in the longer term. Year 2012 is a turning point as emerging economies, such as China and India, start to consume higher quantities of energy than the OECD.

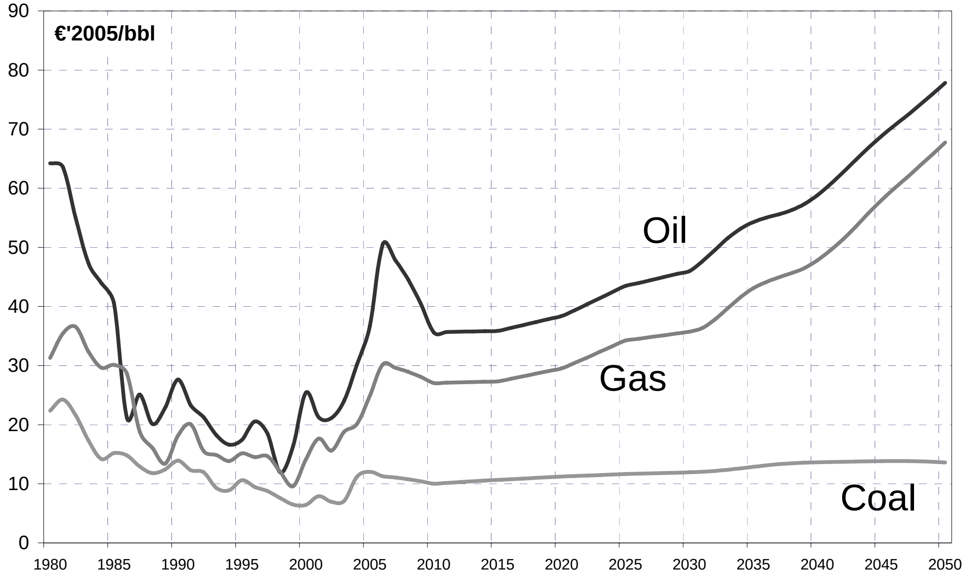
The Baseline scenario reflects an energy pathway influenced by relatively high oil and gas prices (Figure 3) rising substantially higher than forecasts of three or four years ago. Oil prices are projected to stabilise in the short-medium term at a level slightly lower than the 2005-2006 peak and to start rising again in the long run, reaching 46€'2005/bbl[3] in 2030 and almost 80€'2005/bbl in 2050. These long-term oil price trends reflect resource constraints, continuous growth of global energy demand and increasing dependence on non-conventional oil, which has high extraction costs.

Natural gas prices are projected as tightly linked with oil prices. This is not only related to existing long-term gas procurement contracts but also a result of market dynamics, since gas is potentially a substitute for oil and demand elasticity of gas is high.

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.

[3] All monetary figures refer to constant Euros of 2005.

Figure 3: Import prices of hydrocarbons in constant currency



The European baseline outlook (Figure 4) 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. This is in line with historical long-term trends and is a combined effect of structural changes in the economy, saturation and technological progress. Electrification in energy demand is projected to continue under the Baseline scenario, reflecting 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 trend reflects the fact that electricity drives technological progress, comfort and new economic growth in Europe.

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.

Figure 4: Baseline energy and economy indicators

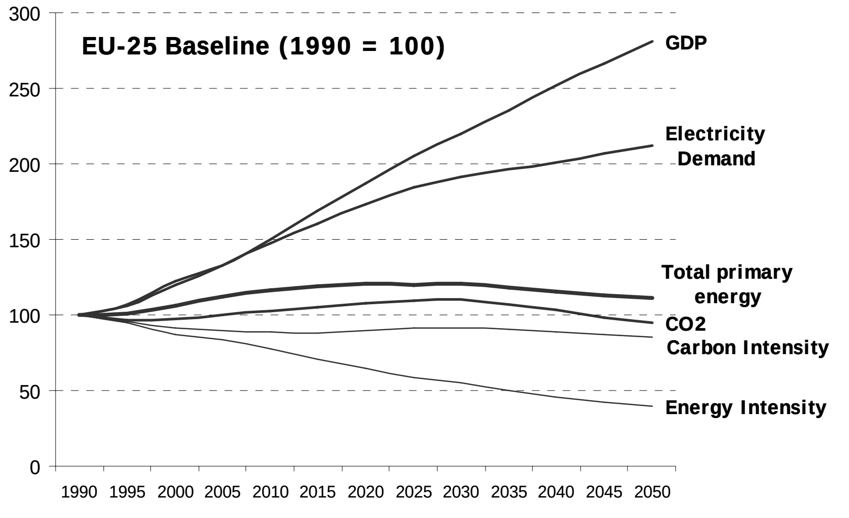
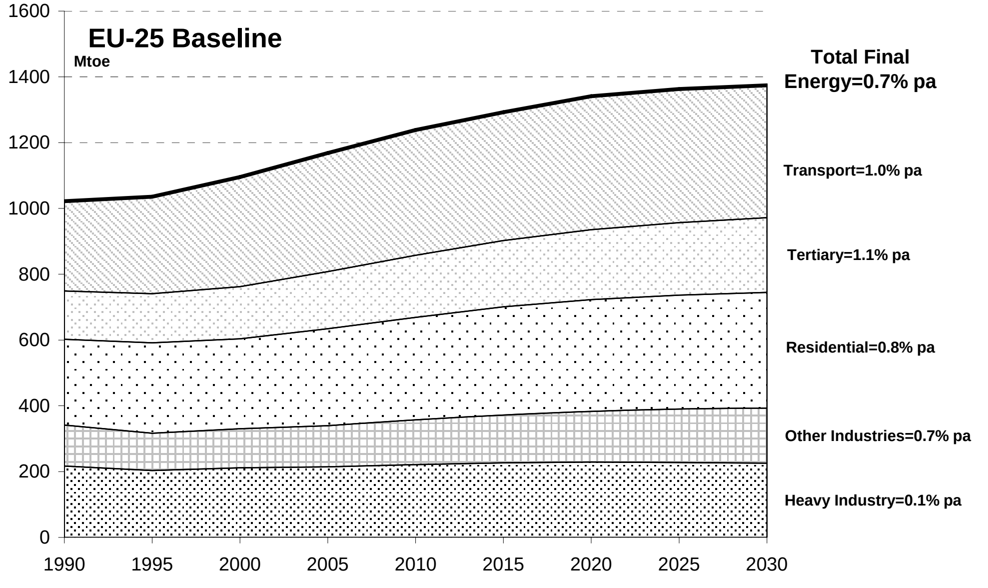


Figure 5 illustrates that energy demand in industry is projected to grow at moderate rates due to considerable reductions in energy intensity related to structural changes towards less energy- intensive manufacturing processes. Relatively high energy demand in the tertiary sector reflects the gradual shift of the European economy towards services. 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 as a result of new specific uses of electricity. The predominant role of the transport sector in final energy demand growth is remarkable. It is only in the long term that the combined effect of transport activity decoupling from economic growth (particularly for passenger transport) and the technological progress of vehicles may lead to a deceleration of energy demand growth in transport. Despite this, transport remains the fastest-growing energy demand sector. This explains the stability of total demand for petroleum products throughout the projection period, except for the period beyond 2030 when oil demand starts to decline smoothly in Europe.

<u>Figure 5</u>: Final energy demand by sector



Increasing demand for electricity implies large expansion of power generation capacity, which has to increase by 50% to 2030 compared to today (Figure 6). To meet rising demand and replace ageing plants, total capacity of 825 GW needs to be constructed in the EU-25.

The nuclear electricity sector, under Baseline conditions, faces four main issues: EU requirements to close a number of plants in new member states; end of conventional lifetime of many plants after 2020; nuclear phase-out in three EU countries; likely decisions in large nuclear countries not to replace the entire nuclear fleet after decommissioning. This explains the decline in nuclear capacity, leading by 2030 to a level which is 40% lower than today, despite 48 GW of new nuclear investment. Under Baseline trends, nuclear energy in 2030 is likely to have a share of just 15% in total power generation, down from 30.8% in 2005.

Technological advances, increased competition in the electricity market favouring low capital cost investment, growth of cogeneration to attain a 28% share in 2030 from 16% in 2005, and high growth of mid-load demand explain why, in the medium-term, there is considerable investment in new gas combined cycle plants, despite high gas prices. The baseline scenario projects that 50% of new thermal plants in the coming fifteen years will be gas combined cycle plants. In the longer term, deterioration of gas-to-coal competitiveness drives a considerable shift in favour of investment in new coal and lignite plants. In the 2015 to 2030 period, it is projected that 250 GW of new coal-fired plants will be built, leading to total capacity of solid fuels plants of 300 GW in 2030, up from 190 GW in 2005.

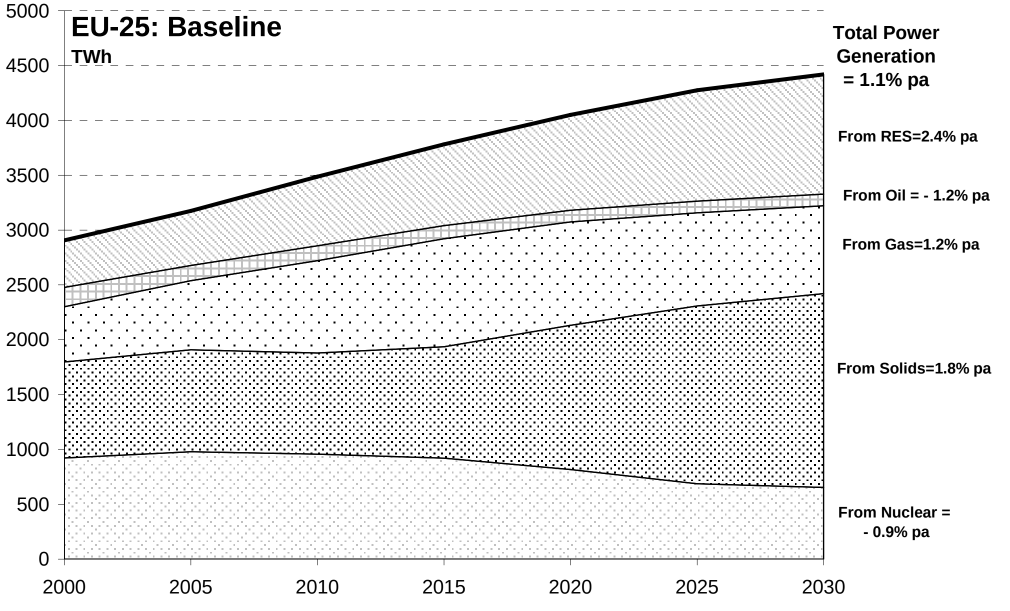
Given that Baseline assumes the continuation of supportive policies for renewables, investment in RES-power plants is found to increase substantially: wind power is projected to reach 190 GW in 2030, of which 47 GW is offshore. Solar photovoltaic is also projected to start rising in the longer term, reaching 10 GW in 2030. Biomass- and waste-burning power plants (including biomass co-firing) are projected to reach a total of 60 GW in 2030. Hydro plants also develop, though at a far lower rate. As a result, electricity generation from renewables is projected to represent 25% of total power generation in 2030, up from 15.7% in 2005.

Because of rising fuel prices and despite technological progress and competition, average electricity prices in Europe are projected under Baseline to increase by 0.2% per year in real terms. Total investment expenditure in power generation is estimated at €1 trillion over the 2005 to 2030 period.

Despite these cost increases, total cost of energy as a percentage of GDP slightly drops over time, from 10.86% in 2005 to 9.57% in 2030.

Under Baseline conditions, carbon dioxide (CO_2) emissions, despite increasing significantly less than GDP and even less than total energy requirements (see Figure 4), 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. This is due to three factors that counterbalance the gains from efficiency and renewables: a) energy demand trends for transport are steady and no substitute to oil really emerges under Baseline; b) coal-fired power generation re-emerges in the long run; c) nuclear generation declines and is substituted by coal. The Baseline scenario projects 10.5% higher emissions in the EU-25 in 2030 than in base year (1990) and 3% higher emissions in 2050.

<u>Figure 6</u>: Power Generation by energy source



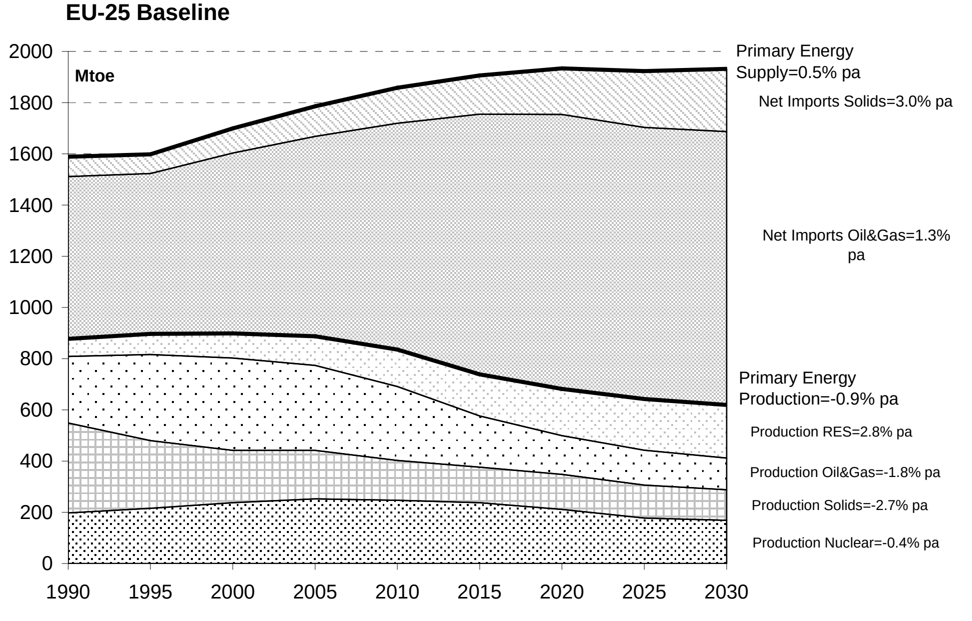
Indigenous production of all energy forms in Europe, except renewables, is projected to decline considerably over time (Figure 7). This trend combined with rising energy needs for oil and gas leads to a serious aggravation of energy dependence of Europe on imports. An analysis about the possible origins 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. 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.

Under these circumstances, energy investors face high uncertainty, because they are exposed to the risk of future climate-related penalties or charges and to the risk of monopoly-driven high price fluctuations or even disruptions in fossil fuel imports. This uncertainty undermines investment, leading to sub-optimal decisions or to postponement of investment. Evidently, this further weakens capacity adequacy in Europe and reduces the potential benefits from technological progress.

Without new policies, the European demand and supply energy system cannot deliver the energy restructuring needed to meet long term climate change objectives

Figure 7: Indigenous Energy Production and Net Imports



4.3. Alternative Scenarios

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 through 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 focuses 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 focuses 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 of the European Commission's January 2007 Strategic Energy Review - "An Energy Policy for Europe" - and its follow-up second Strategic Energy Review in November 2008 – "An EU Energy Security and Solidarity Action Plan" - 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.

4.4. Discussion of results 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.

Table 1 shows 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 the same level as in 2010 and then even drops by 10% in 2050 from its 2005 level. This corresponds to 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 31% in 2030. The share of plug-in hybrid vehicles attains 11% in 2030 and 23% by 2050.

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 (25% in 2050) and greater use of electricity in the *Role of Electricity scenario* (26% in 2050). Hydrogen and fuel cells start to emerge in both scenarios after 2045.

In the two scenarios involving new nuclear policy, nuclear power generation is around 60% higher in 2030 compared to 2005; it more than doubles in 2050. 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.

Renewables achieve their highest share under Efficiency & RES: 45% of all power generation in 2030 and 57% in 2050. This scenario allows renewables to cover 20% of total primary energy requirements in 2030. Compared to the other two scenarios, the additional contribution of renewables is mainly related to the development of biomass.

CCS technology allows considerable avoidance of emissions: under the *Supply* scenario, over 5 billion tons of CO_2 are stored underground from 2020 to 2030, and 14 billion tons from 2030 to 2050. This may be compared against a total CO_2 storage potential of more than 70 billion tons of CO_2.

Power generation investments work out higher than *Baseline* in all alternative scenarios. This is related to premature scrapping of some of the older plants. The considerable restructuring of power generation is accompanied by higher average electricity prices, 20% higher in the *Supply* scenario, 11% higher in the Efficiency and RES scenario and the lowest increase of 9% under the *Role of Electricity* scenario.

Figure 8: Carbon values for equal emissions cap under alternative scenarios

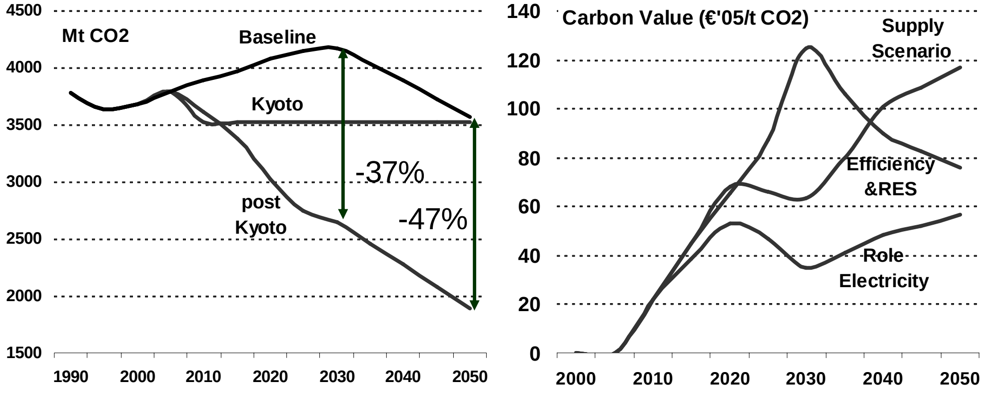
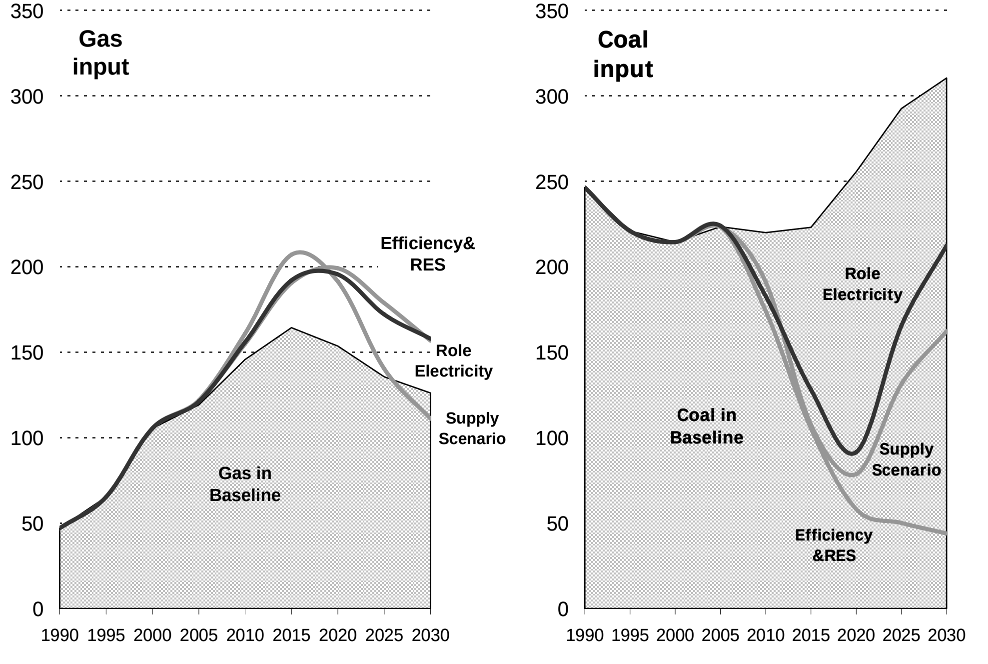


Table 1: Summary of energy system changes (EU-25)

Scenario results for 2030	*Baseline*	*Role of Electricity*	*Supply Scenario*	*Efficiency& RES*
Final Energy Demand (2005=100)	125	113	121	109
Electricity Consumption (2005=100)	145	172	143	127
Electricity Price (2005=100)	111	121	133	123
Electricity from Nuclear (TWh)	654	1,643	1,535	852
Electricity from Renewables (TWh)	1,092	1,359	1,267	1,675
CO2 Stored (cum. Mt)	-	3,797	5,315	-
Power Investment (cum. GW)	928	1,090	950	984

All three alternative scenarios transform power generation into a very low-carbon-intensive energy conversion sector: from 0.43t of CO_2 per MWh in 2000, the emissions from the European Power sector decline to 0.15t/MWh under *Efficiency & RES*, to 0.13 t/MWh under *Role of Electricity* and to as low as 0.06 t/MWh under the *Supply* scenario. In the latter scenario, more than 60% of the CO_2 emitted from power generation in 2030 is captured and stored, compared with 42% in *Role of Electricity*.

Figure 9: Gas and Coal use in Power Generation (EU-25, Mtoe)



The restructuring of the power generation sector is illustrated in Figures 9 and 10 and in Table 2. 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 with CCS facilities take a share between 12 and 19% in 2030 and between 17 and 23% in 2050. The extension of the lifetime of older nuclear plants accounts for 78 GW and, by reducing cost, has a downward effect on electricity generation prices.

Figure 9 and Table 3 also illustrate the importance of securing affordable additional supplies of gas to Europe in the coming 10 to 15 years.

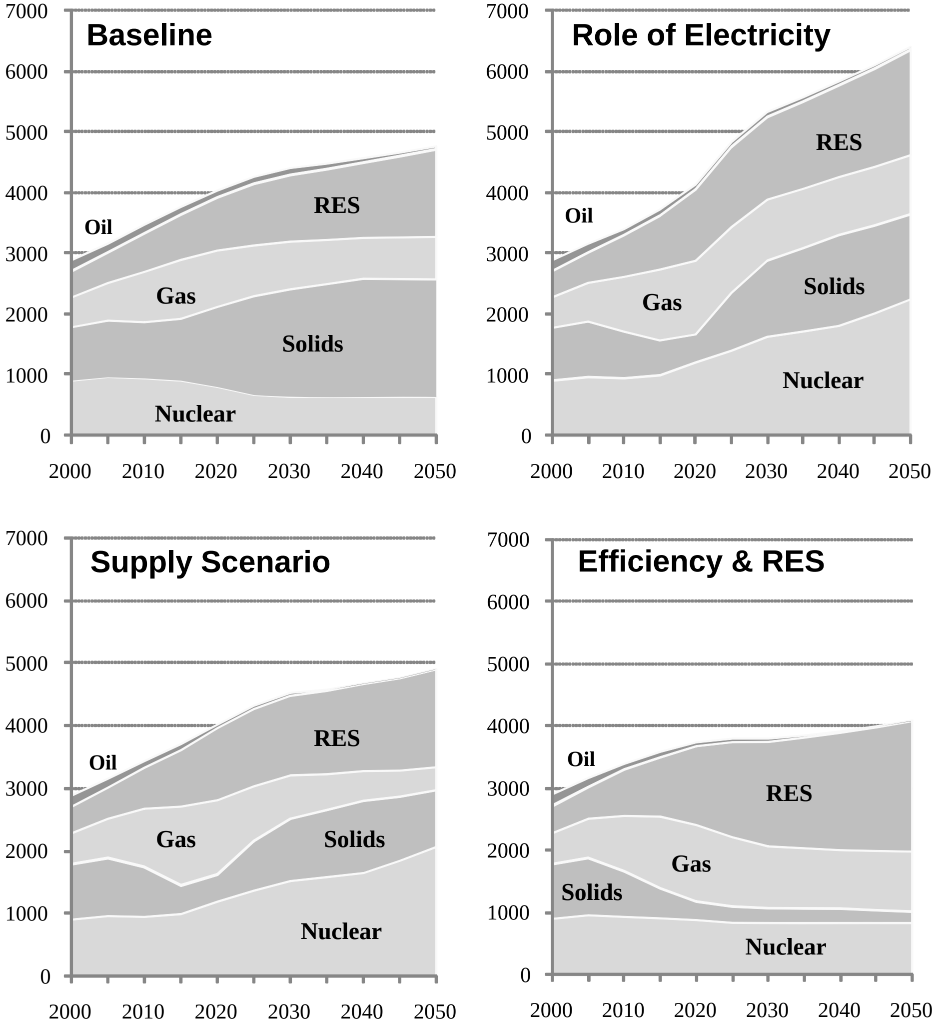
Table 2: Power Sector Investment

Results for 2030	*Baseline*	*Efficiency &RES*	*Supply Scenario*	*Role Electricity*
Power Generation Investment 2000-2030 (GW)	928	984	950	1,090
Gas Plants	261	292	285	336
Solid Fuel Plants	281	67	179	219
Renewables	297	520	368	398
Nuclear	51	76	91	104
Nuclear Plants with Extension of life time (GW)	0	0	78	78
New Plants with CCS Capacity (GW)	0	0	182	143
CHP indicator (% of electricity from CHP)	28.3	31.5	26.8	26.9
Non fossil fuels in electricity generation (%)	39.5	66.2	61.8	56.1
CO_2 Emissions per MWh	0.363	0.153	0.060	0.128

As mentioned above, the *Baseline* scenario involves a dramatic increase in Europe's dependence on energy imports. Table 3 shows that the alternative scenarios, as a result of lower energy use and shifts towards carbon-free sources, involve lower energy imports than *Baseline*.

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 *Role of Electricity* scenarios.

<u>Figure 10</u>: Power Generation by Source in TWh



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 considerable 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.

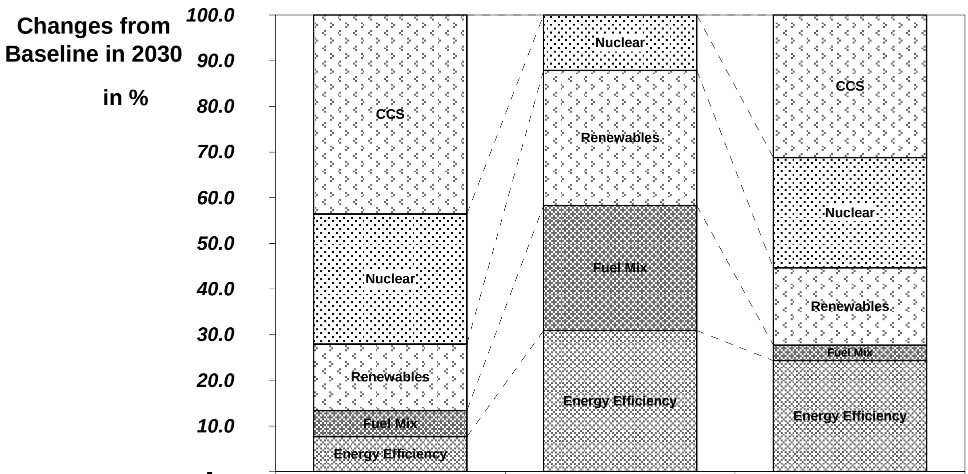
In terms of overall dependence on oil and gas imports, in percentage terms, all alternative scenarios reduce dependence versus *Baseline*. The *Role of Electricity* exhibits a higher performance than the other two scenarios: dependence on oil and gas imports in percentage terms in 2030 approaches the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

Table 3: Incremental net imports of fossil fuels (from 2005)

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

All alternative scenarios avoid emissions of carbon dioxide in equal amounts, but each scenario differs in the way it delivers this carbon mitigation. After applying a decomposition methodology on the model results, one can calculate the net effects of each means of carbon reduction separately for each scenario. This decomposition compares CO_2 emissions in *Baseline* with those in the alternative scenarios.

Figure 11: Decomposition of CO_2 Avoided



	Supply Scenario	Efficiency&RES	Role of Electricity
CCS	43.6	-	31.2
Nuclear	28.5	12.1	24.1
Renewables	14.5	29.6	17.0
Fuel Mix	5.7	27.4	3.4
Energy Efficiency	7.7	30.9	24.3

Figure 11 shows the decomposition of overall emissions avoided under *Baseline* in 2030, on both the energy demand and supply side. 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 above* 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 *Efficiency & RES*, power generation mostly relies on renewables and a change of 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.

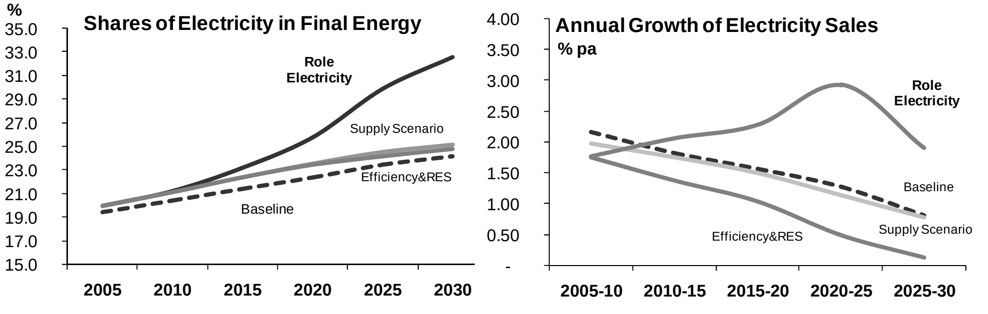
Power generation under the *Supply* scenario mostly relies on nuclear energy and CCS, and less on renewables. Changes of fossil-fuel mix (ie a shift to gas) are lower in this scenario, partly because the CCS technology allows use of coal to be maintained and partly because of the higher potential for nuclear development.

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*[4]. This "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 means will have to be used at non-optimal cost levels.

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.

[4]The indirect use of renewables through heat pumps (the energy extracted from the environment) is not included in the calculation and therefore the indirect impact of the *Role of Electricity* scenario on renewables is not represented. Recent papers from the European Commission have recognised the use of heat pumps as a renewable source of energy, but a standard statistical system on heat pumps and renewables has not yet been established by Eurostat.

Figure 12: Demand of electricity (EU-25)



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 (Table 4).

Table 4: Cost implications

Results for EU - 2030	Baseline	Role Electricity	Supply Scenario	Efficiency& RES
Total Cost of Energy (2005=100)	146	147	161	156
Total Cost of Energy as % of GDP	9.57	9.64	10.61	10.27
Total Unit Cost of Energy (2005=100)	124	139	142	153
Average Price of Electricity (2005=100)	111	121	133	123
Carbon Value(€'05/t CO2)	5	35	63	125
Power Investment in billion € (up to 2030)	933	1,115	1,036	1,039

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.

The *Role of Electricity* scenario holds greater promise for economic development in view of its lower energy costs[5] and is also more robust because its reliance on a broader portfolio of supply and demand solutions

[5] The energy models do not capture this because economic growth is an external constant assumption.

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. However, all three scenarios imply higher expenses in the energy sector than for the rest of the economy. Since energy is a "material" production sector, it usually has a lower multiplier effect than other sectors, which impacts negatively on economic growth. The *Role of Electricity* scenario substitutes more imported energy than other scenarios and at the same time entail lower costs for the rest of the economy. Therefore, this scenario has an overall higher 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.

Table 5: Overall Performance of Alternative Scenarios (Results for 2030 and 2050 expressed as an index, with 2005 = 100)[6]

2005 = 100	Total Cost of Energy		Dependence on Imported Oil & Gas		CO2 Emissions from Energy	
	2030	2050	2030	2050	2030	2050
Baseline	146	159	126	138	110	96
Role Electricity	147	164	105	102	70	50
Supply Scenario	161	169	115	114	70	50
Efficiency&RES	156	164	128	137	70	50

Table 5 shows overall performance in terms of the basic energy policy goals of the European Union. For equal environmental constraints, the *Role of Electricity* scenario performs better than other scenarios in terms of economic competitiveness and Europe's dependence[7] on sensitive imports.

[6] CO_2 emissions were roughly the same in 2005 as 1990.
[7] The ratio "Dependence on Imported Oil and Gas" represents the degree of dependence of the European energy system on sensitive imports and is calculated by dividing net imports of oil and gas by total

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 conclusions as those presented above.

4.5. Concluding remarks from the modelling work

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 CO_2 emissions-reduction target of -30% in 2030 *versus* 1990 levels, 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 enables 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

primary energy requirements.

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.

5. Conclusions and Policy Recommendations

A positive message

The analysis described in this article shows that electricity has the potential to contribute substantially to the three main pillars of European energy policy. It holds the key to substantial reductions in greenhouse gas emissions at reasonable cost to the economy, while at the same time helping to reduce oil and gas dependency.

In order to seize this opportunity, a clear energy policy pathway must be implemented without delay. This *new path* energy policy for the coming decades must be based on five equally important keystones, which must be pro-actively developed in parallel. The simultaneous, pro-active and successful development of these keystones is a prerequisite to untie the energy knot of supply security, climate change and economic competitiveness.

- Unleash the potential of energy efficiency

An energy savings culture must be encouraged among all elements of society, using a variety of tools. Education, incentives, standards and labelling, research and technological development – each one must contribute to fostering energy-efficiency in all sectors of the economy: in households, in industry and service sectors, in transport and through all energy vectors and technologies.

- Develop a low-carbon electricity system by using **all** available options

The next decades must see further progress towards a low-CO_2 electricity generation mix through the pro-active use and development of all available options: hydropower, other renewable energy sources, nuclear energy, and clean fossil-fuel technology including carbon capture and storage. Any policy that tends to exclude specific elements of this balanced portfolio will fail to build a robust and economically-sound low-carbon electricity system.

- Intelligent electrification of the economy

Intelligent electrification of the economy entails two vital imperatives.

The first is to improve electricity efficiency on both the supply and demand side by developing more efficient power generation technologies and by improving efficiency in all kinds of applications including lighting, standby power, motor drives, etc.

The second is to actively develop the far-reaching synergy between CO_2-low electricity supply and energy-efficient demand-side electro-technologies. This process must be accelerated in many industrial or commercial applications and public transport; and must be pro-actively extended to two sectors where electrification allows very substantial progress in terms of energy-efficiency, CO_2-emissions reduction, and oil/gas dependency: heating and cooling through the use of heat pumps; and road transport via plug-in hybrid cars.

- Consistent deployment and a market-oriented approach

The benefits of both existing and new technologies, on both the demand and supply side, must be exploited through practical take-up. This calls for a consistent deployment strategy oriented both to making widespread use of existing technologies, and to making new technologies a business reality through R&D, demonstration programmes, long-term CO_2 price signals and removing barriers to market integration.

Public support policies, where these prove to be necessary, should be organised in such a way as to promote cost-efficiency and to foster speedy integration of new technologies into the market.

The long-term nature of supply-side and of certain demand-side energy investments requires long-term visibility for carbon pricing so as to facilitate the integration of climate change action into investments and business strategies.

- Global cooperation on global issues

The *new path* energy policy reinforces supply security and fosters a worldwide approach to climate change through diversification of energy supplies, international solidarity mechanisms, partnerships between suppliers and users of energy at international level and business level, international cooperation on R&D and demonstration projects, and an international framework for climate change policies and cooperation.

6. References

1. Eurelectric (2007) "The Role of Electricity", Final Report, available at http://www2.eurelectric.org/Content/Default.asp?PageID=730
2. P. Capros, Dr L. Mantzos, Dr N. Kouvaritakis and Dr V. Panos (2007) "The Role of Electricity: Modelling and Scenarios", ICCS/NTUA Report to Eurelectric.
3. Laborelec and Paul Sabatier Toulouse III University (2007) "Lighting", Report to Eurelectric.
4. Anibal T. de Almeida and Paula Fonseca (2007), "Motor Systems", ISR-University of Coimbra Report to Eurelectric.
5. Eurelectric (2007) "Transport: Part I, Automotive", final report.
6. Eurelectric (2007) "Transport: Part II, Rail", final report.
7. Anibal T. de Almeida, Antonio Caetano, João Fong (2007), "Residential and Tertiary Sectors Technologies", ISR-University of Coimbra Report to Eurelectric.
8. R. Belmans, K. Van Reusel et al. (2007), "Industry", report to Eurelectric.
9. VGB PowerTech (2007), "Building Block Energy Supply", Parts I, II, III, Report to Eurelectric.