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COMMISSION STAFF WORKING PAPER

Impact Assessment

Accompanying the document

COMMUNICATION FROM THE COMMISSION TO THE COUNCIL, THE EUROPEAN PARLIAMENT, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Energy Roadmap 2050

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1. SECTION 1: PROCEDURAL ISSUES AND CONSULTATION OF INTERESTED PARTIES

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1.1. Organisation and timing

The IA work started early 2009 with the Reference scenario that is being used for all long-term initiatives of the Commission. An Interservice Steering Group was established early 2009 together with DG CLIMA and MOVE. This Group was also used for the Low Carbon Economy Roadmap and Transport White paper. Problem definition, objectives and design of policy options were presented to the Impact Assessment Steering Group in May 2011 and the final draft IA in July 2011.

The following DGs participated in the Impact Assessment Steering Group: AGRI, CLIMA, COMP, ECFIN, EMPL, ENTR, ENV, INFSO, JRC, LS, MARE, MARKT, MOVE, REGIO, RTD, SANCO, SG, TAXUD.

1.2. Consultation and expertise

On 20 December 2010, the Directorate General for Energy launched a public consultation on the Energy Roadmap. The public consultation[1] was based on an online questionnaire with seven questions, some requiring comments and others in the form of multiple choice[2]. The public consultation was open until 7 March 2011. Some 400 contributions, half from organisations and half from individual citizens, were received. Several Member States sent a formal reply to the public consultation. Given the participation from a broad spectrum of organisations as well as citizens, this public consultation offered insights into a large range of stakeholder opinions. All of the Commission's minimum consultation standards were met. The full report presenting results of the public consultation can be downloaded from Europa website[3].

<u>**Public consultation questions and summary of replies**</u>

Question 1 *How to ensure credibility*: Many contributors emphasised the need for a stable, clear and predictable legislative framework to encourage the necessary investments in the energy sector which generally have a very long lead time. An appropriate analytical framework including transparency on modelling assumptions and results was mentioned by several respondents.

Question 2 *The EU's position in a global policy context:* More than half of all respondents chose "global energy efficiency and demand developments" and "global development of renewable energy" as the most important issues.

Question 3 *Societal challenges and opportunities:* Overall responses were fairly evenly distributed among the different choices. Public acceptance of new infrastructures was seen as important by many.

Question 4 *Policy developments at EU level:* Roughly half of the respondents believe that energy efficiency is among the three most important issues needing more development at the EU level.

1 http://ec.europa.eu/energy/strategies/consultations/20110307_roadmap_2050_en.htm
2 Questions 1, 5 and 7 were open questions and 2, 3, 4 and 6 were multiple choice.
3 http://ec.europa.eu/energy/strategies/consultations/20110307_roadmap_2050_en.htm

Question 5 *Milestones in the transition:* Across all industries and NGOs, intermediate targets, checkpoints and regular updates towards 2050 were recommended. However, the decarbonisation roadmap should be flexible enough to allow the route to be changed along the way.

Question 6 *Key drivers for the future energy mix:* About half of all respondents believe that global fossil fuel prices in relation to costs of domestic energy resources and long term security of supply will be the most likely key drivers of the future European energy mix.

Question 7 *Additional thoughts and contributions:* There was considerable divergence in opinions on the best way to decarbonise the energy sector in terms of market intervention as well as in the selection of a preferred technology option to be pursued.

In addition to the public consultation, representatives from the Directorate General for Energy and Commissioner Oettinger met numerous stakeholders individually and received many reports prepared by stakeholders on this topic. A comparison of stakeholder reports is presented in Annex 2.

An informal Energy Council took place on 2-3 May 2011 where ministers had a full-day discussion on the Energy Roadmap 2050. A meeting of Member State (MS) energy experts on the Roadmap also took place on 25 May 2011. The European Commission (EC) presented the problem definition, objectives and design of policy options of this Impact Assessment (IA) report. An Advisory Group of 15 highly-regarded experts mainly from academia and international institutions was established to support the work on the preparation of the Roadmap A presentation on the Roadmap was also given to the European sectoral social dialogue committee in the electricity sector on 14 December 2010.

The Commission contracted the National Technical University of Athens to model scenarios underpinning the IA analysis. Similarly to previous modelling exercises with the PRIMES model, the Commission discloses a lot of details about the PRIMES modelling system, modelling assumptions and modelling results which can be found in sections 4 and 5 as well as the annex 1 including an extensive section on macroeconomic, energy import prices, technology (capital costs of different technologies in power generation, appliances and transport) and policy assumptions. The PRIMES model was peer-reviewed by a group of recognised modelling experts in September 2011 with the conclusion that the model is suitable for the purpose of complex energy system modelling.

1.3. Opinion of the Impact Assessment Board (IAB)

The IA report was discussed at the IAB hearing on 14 September 2011 and the IAB issued a positive opinion acknowledging the quality of the technical analysis and modelling underpinning the Roadmap and the Impact Assessment. The IAB recommended to improve the report in the following aspects: (1) to bring key findings of the evaluation of on-going policies into the IA report; (2) to consider an alternative policy scenario relying on a more relaxed assumption about the global climate deal; (3) to better describe scenarios and underlying assumptions; (4) to improve assessment of non-energy related impacts (employment, skills and knowledge gaps) and (5) to present stakeholder views in a more transparent way.

As a response to these suggestions, the evaluation part was reinforced; the issue of carbon leakage and external competitiveness was added to the problem definition as well as section 4.1. Methodology, while the part on competitiveness issues was expanded in Annex 1; policy options were described in more detail and the assessment of employment impacts was improved.

2. SECTION 2: PROBLEM DEFINITION

2.1. Context

(i) In the 2nd Strategic Energy Review (November 2008), the Commission undertook to prepare an energy policy roadmap towards a low carbon energy system in 2050. The Europe 2020 strategy includes a general commitment to establish a vision of structural and technological changes required to move to a low carbon, resource efficient and climate resilient economy by 2050.

(ii) The Commission's approach to decarbonisation is firmly grounded in the EU's growth agenda, set out in the Europe 2020 strategy, including the Resource Efficient Europe Flagship Initiative[4]. The Communication "Energy 2020 - A strategy for competitive, sustainable and secure energy" paves the way to 2020 stressing the three pillars of the EU's energy policy: competitiveness, security of supply and sustainability, building on the Climate and Energy package adopted in June 2009.

(iii) The European Council (October 2009) supports an EU objective, in the context of necessary reductions according to the IPCC by developed countries as a group, to reduce GHG emissions by 80-95% by 2050 compared to 1990 levels[5]. The European Parliament similarly endorsed the need to set a long-term GHG emissions reduction target of at least 80% by 2050 for the EU and the other developed countries[6].

(iv) The European Council (February 2011) confirms this emissions reduction commitment and recognises that it will require a revolution in energy systems, which must start now. It requests that due consideration should be given to fixing intermediary stages towards reaching the 2050 objective.

(v) The Roadmap for moving to a competitive low carbon economy in 2050[7] makes the economic case for decarbonisation and shows that the targeted 80-95% GHG emissions reduction by 2050 will have to be met largely domestically. Intermediate milestones for a cost-efficient pathway, e.g. 40% domestic reduction by 2030, and sectoral milestones expressed as ranges of GHG emissions reductions in 2030 and 2050 were put forward.

(vi) The Commission is now preparing sectoral roadmaps exploring the dynamics within the sector and the interplay of decarbonisation[8] and other sectoral objectives. The Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system[9] aims to introduce profound changes in passenger and freight transport patterns,

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4 COM(2011) 21, 26 January

5 European Council, Brussels, 29/30 October 2009, Presidency conclusions. 15265/1/09

6 European Parliament resolution of 4 February 2009 on "2050: The future begins today – Recommendations for the EU's future integrated policy on climate change; resolution of 11 March 2009 on an EU strategy for a comprehensive climate change agreement in Copenhagen and the adequate provision of financing for climate change policy; resolution of 25 November 2009 on the EU strategy for the Copenhagen Conference on Climate Change (COP 15)

7 COM(2011)112, 8 March

8 Both roadmaps provide analysis under global climate action assumption.

9 COM(2011)144, 28 March

resulting in a competitive transport sector which allows increased mobility, cuts CO2 emissions to 60% below 1990 levels by 2050 and breaks the transport system's dependence on oil. A Roadmap to a Resource Efficient Europe, also planned for 2011, builds on and complements other initiatives, focusing on increasing resource productivity and decoupling economic growth from resource use.

This IA is a key part of initiatives to deliver on a resource Efficient Europe, one of the 7 flagships of the Europe 2020 strategy[10]. It aims at further developing the decarbonisation analysis of the energy sector as presented in the Low Carbon Economy Roadmap in March 2011, with particular attention to all three EU energy policy objectives - **energy security, sustainability and competitiveness.**

2.2. What is the problem?

The well-being of people, industry and economy depends on safe, secure, sustainable and affordable energy. Energy is a daily need in a modern world and is mostly taken for granted in Europe. The energy system and its organisation evolved over centuries if not millenaries using different fuels and distribution systems to cover basic needs such as food preparation, protection against winter temperatures and production of tools e.g. via metal melting. Over the last century this has concerned delivering heat and warm water as well as industrial and transport fuels and electricity to consumers. There has been a significant increase in energy production and consumption over the last 100 years providing more comfort and individual freedom but at the same time polluting the environment and (at least partially) depleting existing reserves. Our current energy system and ways of producing, transforming and consuming energy are unsustainable due to:

(1) High GHG emissions of which the great majority is directly or indirectly linked to energy[11] which are not compatible with the EU and global objectives of limiting global climate change to a temperature increase of 2ºC to avoid dangerous impacts[12] (even though the EU contribution to global emissions is low and will decline in particular if other regions make no or little efforts on decarbonisation,[13] industrialised countries should keep their leading role in the fight against climate change);

(2) Security of supply risks, notably those related to:

- high dependence on foreign sources of energy imported from a limited number of suppliers (EU27 currently imports 83.5% of its oil and 64.2% of its gas consumption; overall import dependency is around 54% and is projected to slightly increase by 2050), including supplies from politically unstable regions;

[10] COM(2010) 2020, EUROPE 2020 - A strategy for smart, sustainable and inclusive growth

[11] Energy related emissions account for almost 80% of the EU’s total greenhouse gas emissions with the energy sector representing 31%; transport 19%; industry 13%; households 9% and others 7 %.

[12] Other important issues related to the environmental impacts of our energy system include air pollution, water pollution, wastes and impacts to ecosystems and their services. Indeed, negative trends in land, water (fresh and marine) and air quality depend on how energy is generated and used: combustion processes, especially in the case of small unregulated biomass plants, give rise to gaseous emissions and cause local air quality and regional acidification; fossil and nuclear fuel cycles (as well as geothermal production) emit some radiation and generate waste of different levels of toxicity; intensification of biomass use (and of biomass imports) may lead to forest degradation; bioliquids may lead to GHG emissions and direct and indirect land use driving prices for food up globally; last but not least, large hydropower dams flood land and may cause silting of rivers.

[13] International Energy Agency, World Energy Outlook 2010. The EU contribution would decline from 13% of global CO2 at present to 8% in 2035 if all world regions are only pursuing current policies.

- gradual depletion of fossil fuel resources and rising global competition for energy resources;

- increasing electrification from more variable sources (e.g. solar PV and wind) which poses new challenges to the grid to ensure uninterrupted electricity deliveries;

- low resilience to natural or man-made disasters and adverse effects of climate change;

(3) Competitiveness risks related to high energy costs and underinvestment. External competitiveness of the European industry vis-à-vis its international competitors is another crucial aspect determining the design and timing of EU energy and climate action. While it is important to sustain first mover advantage and industrial leadership it should also be assessed whether "early" action comes at a cost of comparatively high carbon, fuel and electricity prices for industry compared to action undertaken in the rest of the world.

It will take decades to steer our energy systems onto a more secure and sustainable path. In addition, there is no silver bullet to achieve it. There is no single energy source that is abundant and that has no drawbacks in terms of its sustainability, security of supply and competitiveness (price). That is why the solution will require trade-offs and why the market alone under the current regulatory environment might fail to deliver. The decisions to set us on the right path are needed urgently as failing to achieve a well-functioning European energy market will only increase the costs for consumers and put Europe's competitiveness at risk. Significant investments will however be needed in the near future to replace energy assets in order to guarantee a similar level of comfort to citizens at affordable prices; assure secure and competitive supplies of energy inputs to businesses and preserve the environment. The energy challenge is thus one of the greatest tests which Europe has to face.

Relying on more low-carbon, domestic (i.e. intra EU) or more diversified sources of energy, produced and consumed in an efficient way, can bring significant benefits not only for the environment, competitiveness and security of energy supply but also in terms of economic growth, employment, regional development and innovation. What are the barriers? Why is the shift to an energy system using low-carbon, more competitive and more diversified sources not, or too slowly happening?

2.3. Underlying drivers of the problem

There are several factors that hamper the shift:

2.3.1. General barriers

1) Energy market prices do not fully reflect all costs to society in terms of pollution, GHG emissions, resource depletion, land use, air quality, waste and geopolitical dependency. Therefore, user and producer choices are made on the basis of inadequate energy prices that do not reflect true costs for society.

2) Inertia of the physical system

The majority of investments in the energy system are long-term assets, sometimes requiring long lead times, and having life times of 30-60 years, leading to significant lock-in effects. Any change to the system materialises only gradually. Current market structure and infrastructures can discourage new technology development, since infrastructure, market design, grid management and development require adaptation and modernisation which represent additional costs which face resistance from industry.

3) Public perception and mindset of the users

General public perception of the risks related to the construction of new power plants (large-scale RES, nuclear, low-carbon fossil) and infrastructure needed to introduce large shares of renewables (which additionally implies new grid lines and large energy storage technologies) or of CO2 storage can be more negative than expert judgements. Public acceptance was also acknowledged as important by many respondents in public consultation. It can also take a long time and require adequate incentives or regulation to persuade people to change the way they heat their houses, transport themselves, etc.

4) Uncertainty concerning technological, demand, prices and market design developments

The energy system is characterised by a large proportion of long-term fixed costs that need to be recovered over several decades. Uncertainty about future technologies, energy demand development, market integration and rules[14], carbon and fuel prices, availability of infrastructures can significantly increase investor risks and costs, and make consumers and businesses reluctant to invest. Private investors can cope well with some categories of risks but policy makers and regulators can contribute to decreasing the uncertainties as regards political and regulatory risks.

5) Imperfect markets

There is weak competition in some Member States where markets are still dominated by incumbents. In particular, the absence or lack of effective non-discriminatory third party access to infrastructure can constitute an entry barrier for new entrants. Another factor is market myopia, i.e. the fact that long-term investments are not necessarily pursued by market actors who are generally drawn towards shorter-term gains.

Regarding new infrastructure investments, it can be difficult to clearly identify the beneficiaries, and therefore efficiently allocate the costs of new investments. In addition, in liberalised markets with various players, interdependencies might impose additional efforts to coordinate some investments (it is unrealistic to expect wind power plants to be constructed in the North Sea if no adequate grid is built).

In some Member States developing markets for energy efficiency services and decentralised RES are faced with a low number of actors on the supply side (lack of qualified labour force) as well as on the demand side (low levels of consumer awareness partly as a consequence of the ongoing rapid technological advances) and the lack of enabling regulatory framework. This has a particularly negative effect on the uptake of energy services companies (ESCOs) that can provide integrated energy saving solutions together with financing schemes. Renewable energy can also suffer from market designs that have been developed alongside the development and optimisation of centralised power generation and trading.

[14] As regards market developments, questions about adequacy and intensification of incentives for investments; future of support schemes for RES and other technologies; support mechanisms/regulations for energy efficiency; etc might arise.

2.3.2. Sector specific barriers

Besides these factors and based on **an evaluation of ongoing policies**[15], there are problems specific to energy efficiency, infrastructure, security of supply and low-carbon generation technologies which are discouraging investments.

Energy efficiency

Though a number of initiatives were undertaken at EU level since the mid-1990s, the European Energy Efficiency Action Plan[16] created a framework of legislation, policies and measures with a view to realise the 20% energy efficiency and saving objective. After years of growth, the EU primary energy consumption has stabilized in 2005 and 2006 at around 1,825 Mtoe and decreased in 2007, 2008 and 2009 to reach around 1,700 Mtoe[17]. Energy intensity kept improving. For the first time, the latest business-as-usual scenario projections (PRIMES 2009) show a break in the trend of ever-increasing energy demand in the EU27[18].

However, the EU is far from reaching its 20% objective. The projections indicate that with the rates of implementation of the current energy efficiency policies in Member States only half of the objective might be achieved by 2020[19]. Furthermore, while the economic crisis contributed to this decrease in energy consumption, it has also negatively impacted energy efficiency investment decisions at all levels - public, commercial and private. As a response to this, the Commission has recently adopted two new initiatives - an Energy Efficiency Plan[20] and a Directive on Energy Efficiency - aiming at stepping up efforts towards the 20% target.

In addition to the above mentioned barriers, there are many examples of **split incentives or principal-agent** market failures in the energy sector where the decision maker may be partially detached from the price signals. For example, landlords are often the decision-makers about renovation of buildings, but it is usually tenants that pay the energy bills and benefit from their reduction, giving landlords little reason to invest.

Internal market

The process of opening the EU energy markets to competition started ten years ago. It has allowed EU citizens and industries to benefit in terms of more choice, more competition for a better service and improved security of supply. Since July 2007, all consumers in all EU countries have been free to switch their suppliers of gas and electricity.

Independent national regulatory authorities have been established in each EU country to ensure that suppliers and network companies operate correctly and actually provide the services promised to their customers. An inquiry into the electricity and gas sectors published in January 2007[21] revealed that too many barriers to competition and too many differences across the Member States remain. In 2007 and 2008, a great deal of effort was put into enhancing competition on the wholesale market; significant progress was made through the

15 SEC(2010) 1346 final, COMMISSION STAFF WORKING DOCUMENT State of play in the EU energy policy

16 COM(2006) 545.

17 2009 Eurostat data are the latest official data.

18 The scenarios of the "Energy trends 2030" (update 2009) are accessible at the following address: http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf

19 COM (2011) 109

20 Communication Energy Efficiency Plan 2011, SEC(2011) 280 final, SEC(2011) 277 final, SEC(2011) 275 final, SEC(2011) 276 final, SEC(2011) 278 final, SEC(2011) 279 final

21 COM(2006) 851.

regional initiatives. However, the Benchmarking Report adopted in 2009[22] still showed a mixed picture of the accomplishment of the internal market and revealed in particular that there are still high levels of concentration on the retail and wholesale markets and a lack of liquidity.

To remedy the situation, the Commission came forward with the third internal energy market liberalisation package. It foresees the effective separation of supply and production activities to make the market accessible for all suppliers, the harmonization of powers of national regulators, better cross-border regulation to promote new investments and cross-border trade, effective transparency, as well as assuring that EU and third country companies compete in the EU on an equal footing. For the electricity market, a target model has been agreed in the context of the Florence regulatory forum and for gas markets a target model is under development.

Infrastructure

Tariff regulation - Transmission is a mostly regulated business at national level and cost allocation to final beneficiaries can be difficult for large trans-European infrastructure. Tariff regulation in most Member States has been based on the principle of cost-efficiency, allowing recovery of costs only for projects based on real market needs or cheapest available solutions, but some externalities, such as innovation, security of supply, solidarity aspects or other wider European benefits may not always be fully taken into account. For infrastructure networks that are entirely new, such as electricity highways or CO2 transport infrastructure, it is likely to be of public interest to ensure that the first investments are compatible with later, more efficient network solutions.

In the EU internal energy market, a key tool to promote interconnections is the trans-European energy networks (TEN-E) programme which has positively contributed to the development and operation of the internal energy market and increased security of supply[23]. Despite the progress achieved, the dramatic changes to the EU energy policy framework in recent years call for a review of the TEN-E framework. The programme has responded too slowly to the major energy and climate goals of today, and is poorly equipped to deal with the growing challenges that will arise from the 2020 and 2050 ambitions. In 2009, as the financial crisis unfolded, EU institutions agreed on the European Energy Programme for Recovery (EEPR)[24] which was endowed with a €3,980 million financial envelope in support of gas and electricity interconnection projects, offshore wind projects as well as carbon capture and storage projects.

Security of supply

EU Energy import dependency for all fuels is 54%. More importantly, the EU is vulnerable to the increasing supply of some commodities by global oligopolies which can create internal and external imbalances. EU experiences of gas supply interruptions in early 2006, 2008, 2009 and 2010, as well as the EU's strong dependence on imports of petroleum products and the geopolitical uncertainty in many producer regions led to the adoption of the Regulation concerning measures to safeguard security of gas supply[25].

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22 COM(2010) 84.

23 SEC(2010) 505.

24 Regulation (EC) No 663/2009 of the European Parliament and of the Council of 13 July 2009 establishing a programme to aid economic recovery by granting Community financial assistance to projects in the field of energy.

25 Regulation 994/2010

Since 1968, EU legislation imposes an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products that can be used in the event of a supply crisis and a new directive[26] adopted in September 2009 aligns stockholding obligations with those of the International Energy Agency.
Electricity blackouts in the EU in November 2006 highlighted the need to define clear operational standards for transmission networks and for correct maintenance and development of the network. Therefore, in order to ensure the functioning of the internal energy market, the EU established obligations for Member States to safeguard security of electricity supply and undertake significant investment in electricity networks[27].

Low-carbon generation technologies
All low carbon technologies are reliant upon a strong carbon price or other regulatory measures. As well as continuous R&D funding, long-term market or regulatory signals to investors are needed.

Renewables
Some renewables are currently at early development stage, insofar as they often have higher costs than alternatives, though they form part of a sector with rapid technological developments and significantly declining production costs resulting from early economies of scale and technology learning.

Renewable energy production has grown rapidly in the last ten years. The Green electricity Directive (2001/77) and the Biofuels Directive (2003/30) aimed to stimulate an increase in the consumption of renewable energy. The former established an overall EU target of 21% and national indicative targets for the RES shares in gross electricity consumption by 2010. The latter required that all Member States should ensure that at least 5.75% of their petrol and diesel for transport comes from renewable fuels. Despite significant growth, the latest EUROSTAT data indicate that 2010 targets will not be met.[28] The Renewable Energy Directive[29] sets out binding targets for all Member State to achieve the 20% renewable energy target for the EU by 2020 as well as a 10% target for the share of renewable energy in transport. It also addresses the problems of administrative barriers to the development of renewables and their integration in the grids and sustainability requirements for biofuels. According to the Communication on "Renewable Energy: Progressing towards the 2020 target", Member States are on track to reach their overall renewable energy target as well as the sub-target for renewable energy in transport.

Table 1: Renewable energy developments and defined targets.

Share of renewable energy in…	**2001**	**Most recent data**	**Target 2010 (indicative)**	**Target 2020 (binding)**
electricity generation	13.4% (36 Mtoe)	16. 6 % (48 Mtoe - 2008)	21%	no
transport	0.3% (1 Mtoe)	3. 5 % (11 Mtoe - 2008)	5.75%[30]	10%[31][3]

[26] Council Directive 2009/119/EC of 14 September 2009 imposing an obligation on Member States to maintain minimum stocks of crude oil and / or petroleum products.
[27] Directive 2005/89/EC of the EP and of the Council of 18 January 2006 concerning measures to safeguard security of electricity supply and infrastructure investment.
[28] COM(2009) 192, The renewable energy progress report.
[29] 2009/28.
[30] Relates to share of biofuels and other renewable fuels in petrol and diesel for transport
[31] The 2020 target can be fulfilled through the use of renewable energy in all types of transport. Energy use in maritime and air transport counts only for the numerator, not the denominator.

heating[32]	9.1% (52 Mtoe)	12 % (67 Mtoe - 2008)	no target	no
Gross final energy consumption	**7.6% (89 Mtoe)**	**10.6 % (132 Mtoe - 2009)**	**no target[33]**	**20%**
Gross inland consumption	5.8% (101 Mtoe)	9.0% (153 Mtoe)	12%	no

Nuclear

The EU-27 has the largest number of commercial nuclear power stations in the world: some 150 nuclear reactors are in operation, providing around 30% of the EU's electricity and 60% of low carbon electricity. Although nuclear is a proven technology, in some MS it faces uncertainties regarding public acceptance due to risk perception and often also due to lacking implementation of available technical solutions for long term disposal of nuclear waste. The nuclear accident in Japan could further aggravate public acceptance problems in some MS while possible further increased safety requirements might affect the competitiveness of existing nuclear generation capacities in some MS.

Nuclear safety is and will remain one of the absolute priorities of the EU. A Directive establishing the basic framework for nuclear safety[34] adopted in 2009 provides a Community framework in order to maintain and promote the continuous improvement of nuclear safety. When this Directive will be implemented the EU will be the first major regional nuclear player with common binding nuclear safety rules. On 3 November 2010, the European Commission also proposed a Directive which sets safety standards for disposing spent fuel and radioactive waste.

CCS

As a new and developing industry, CCS faces similar challenges to innovative renewable energy technologies. At present, it is in the early commercial-scale demonstration phase, and is ambitiously striving to be commercially viable soon after 2020. But facing a number of problems, its progress is currently challenged by issues that include financing and public perception concerns in some Member States.

The European Council of March 2007 urged to work towards strengthening R&D and developing the necessary technical, economic and regulatory framework to remove existing legal barriers and to bring environmentally safe CCS to deployment. In 2008, the European Council made a commitment to supporting the design, construction and operation of CCS in up to 12 large-scale demonstration plants by 2015. Demonstration of the technology in commercial plants is considered to be an essential step towards commercialisation of CCS to demonstrate the environmental safety and economic viability of the technology, which is also dependent on strong carbon prices. The CCS Directive[35] establishes a comprehensive legal framework to safely manage the environmental aspects of capture, transport and the geological storage of CO2. The revised ETS Directive ensures that safely stored CO2 is not regarded as emitted and provides therefore a financial incentive for CCS. In addition, 300 million allowances from the New Entrants Reserve (NER) shall be available to support

32 "Heating" is a catch-all term for energy consumption that is neither for transport nor in the form of electricity.

33 A 1997 White Paper established an indicative target of 12% of primary energy consumption in 2010, which was used to derive the 21% target for RES in power generation in 2010

34 Council Directive 2009/71/Euratom of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations.

35 Directive 2009/31/EC on the geological storage of carbon dioxide adopted as part of the Climate and Energy Package in 2009

commercial-scale CCS and innovative RES demonstration projects under the NER300 funding programme, thus complementing and going beyond funding already provided by the EEPR. CCS is also an important option for decarbonisation of several heavy industries[36]. Moreover, CCS has the potential to deliver carbon-negative power, if it is combined with biomass combustion or co-firing.

As the Energy Roadmap 2050 is a broad policy document without having the ambition of defining individual policy measures, this IA tries to present a broad picture of the challenges and barriers but will not propose solutions to all of them.

2.4. Business as usual developments

2.4.1. Modelling approach

The Commission has carried out an analysis of possible future developments in a scenario of unchanged policies, the so-called **"Reference scenario"**. The Reference scenario was also used in the IA for the "Low-carbon economy 2050 roadmap" and IA for the "White Paper on Transport". The Reference scenario is a projection, not a forecast, of developments in the absence of new policies beyond those adopted by March 2010. It therefore reflects both achievements and deficiencies of the policies already in place. In order to take into account the most recent developments (higher energy prices and effects of the nuclear accident in Japan) and the latest policies on energy efficiency, energy taxation and infrastructure adopted or planned after March 2010, an additional scenario called **Current Policy Initiatives scenario (CPI)** was modelled.

Both scenarios build on a modelling framework including PRIMES, PROMETHEUS, GAINS and GEM-E3 models. The PRIMES model is a modelling system that simulates a market equilibrium solution for energy supply and demand. The model is organized in sub-models (modules), each one representing the behaviour of a specific (or representative) agent, a demander and/or a supplier of energy. GAINS complements PRIMES with consistent estimates of non-CO2 emissions and their contribution to reach the policy targets included in the reference scenario. PROMETHEUS is a stochastic world energy model used for determining fossil fuel import prices, while the results of the GEM-E3 general equilibrium model are used as inputs of macro-economic (e.g. GDP) and sectoral numbers (e.g. sectoral value added) for PRIMES. Several EU scenarios were established at different points in time using a framework contract with National Technical University of Athens (author and owner of the PRIMES model).

2.4.2. Assumptions

The Reference scenario 2050 includes current trends and recent Eurostat and EPC/ECFIN long term projections on population and economic development. It takes into account the upward trend of import fuel prices in a highly volatile world energy price environment. Economic decisions are driven by market forces and technological progress in the framework of concrete national and EU policies and measures implemented by March 2010. The 2020 targets for RES and GHG will be achieved in this scenario, but there is no assumption on targets for later years besides annual reduction of the cap in the ETS directive.

The CPI scenario builds on the same macroeconomic framework and includes policy initiatives adopted after March 2010 or policy initiatives currently being planned as well as updated technology assumptions for nuclear and electric vehicles.

[36] According to recent Technology Roadmap from IEA/ UNIDO, CCS could reduce CO2 emissions by up to 4.0 gigatonnes annually by 2050 in industrial applications, accounting for 9% of the reductions needed to halve energy-related CO2 emissions by 2050.

The main assumptions used for both scenarios are presented in table 2 and all assumptions and more detailed description of results can be found in Annex 1 (part A).

Table 2: Main assumptions in the Reference scenario 2050 and Current Policy Initiatives Scenario

GDP growth rate: 1.7 % pa on average for 2010-2050

Oil price: 106 $/barrel in 2030 and 127 $/barrel in 2050 (in year 2008 dollars)[37]

Main policies included (Reference scenario): Eco-design and Labelling directives adopted by March 2010; Recast of the Energy Performance of Buildings Directive, EU ETS directive; RES directive (20% target); Effort Sharing Decision (non-ETS part of the 20% GHG target); Regulation on CO2 from cars and vans.

Main policies included (Current Policy Initiatives scenario) in addition to those already included in the Reference scenario 2050: Energy efficiency Plan; facilitation policies for infrastructure and updated investments plans based on ENTSO-e Ten Year Network Development Plan; Nuclear Safety Directive; Waste management Directive; revised Energy Taxation Directive

Consequences of the Japanese nuclear accident leading to abandon of nuclear programme in Italy, nuclear phase-out in Germany and in case of nuclear lifetime extension up to 20% higher generation costs reflecting higher safety requirements as well as introduction of a risk premium for new nuclear power plants; revisiting of progress on CCS in demonstration projects and policies and initiatives leading to slightly higher uptake of electric vehicles.

Costs for technologies: Technology parameters are exogenous in the PRIMES modelling and their values are based on current databases, various studies and expert judgement and are regularly compared to other leading institutions. Technologies are assumed to develop over time and to follow learning curves which are exogenously adjusted to reflect the technology assumptions of a scenario. Overall, mature fossil fuel, nuclear as well as large hydroelectric technologies exhibit rather stable technology costs, except for innovative concepts such as 3rd generation nuclear power plants or carbon capture and storage (CCS), where costs decline with further RTD and more technology experience. Similar developments are assumed for new renewable technologies, such as off-shore wind and solar PV as has been witnessed in the past for most energy technologies (e.g. on-shore wind or more recently solar energy).

Drivers: Within these framework conditions market forces drive energy and emission developments. Economic actors optimise their supply and demand behaviour while the simulation of energy markets in the model derives energy prices, which in turn influence the behaviour of energy actors (power generators, various industrial and service consumers, households, transport, etc). The Reference and CPI scenarios do not assume any additional policies. The model provides a simulation of what the interplay of market forces in the current economic, world energy, policy and technology framework would bring about if no new policies would be put in place.

All scenarios are built on assumptions of perfect foresight and "representative" consumer leading to a very high certainty on regulatory framework for investors and rather optimistic deployment of technologies by households and services that will be challenging to ensure in practice.

2.4.3. Energy developments

Energy consumption

Primary energy consumption peaked in 2006, from which point it decreases slightly up to 2050 (-4%). This is despite economic growth leading to a doubling of GDP between 2005 and 2050.

Final energy consumption continues rising until 2020, after which demand stabilises as more efficient technologies have by then reached market maturity and the additional energy

[37] Short-term projections for oil, gas and coal prices were slightly revised according to the latest developments in the Reference scenario as compared to the version used in the low carbon economy roadmap.

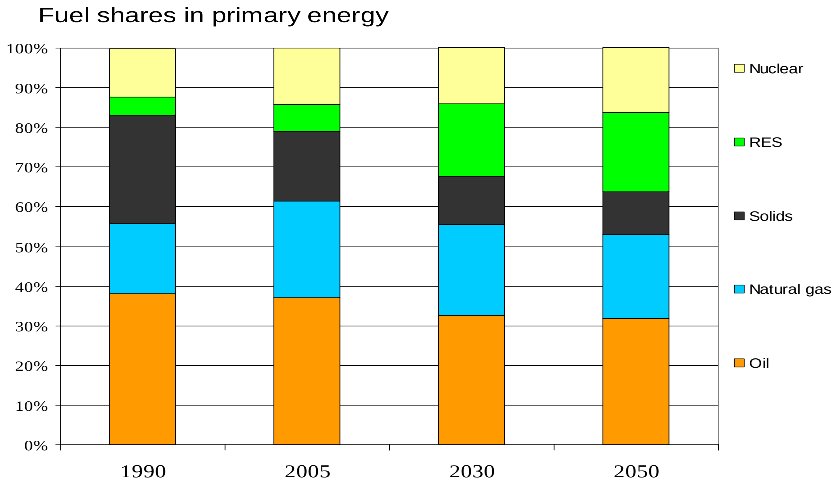
efficiency of the appliances is sufficient to compensate for increased demand. The share of sectors remains broadly stable with transport remaining the biggest single consumer accounting for 32% in 2050; the industrial share increases slightly while that of households declines a bit.

In the CPI scenario, further energy savings are brought about mainly by energy efficiency measures for households and services sector and efficiency improvements in energy transformation in the short to medium term leading to further declines in final energy demand which remains 4-6% below the Reference scenario. There are marked changes also at the level of primary demand in 2020 (-5.0%); 2030 (-5.8%) and 2050 (-8.4%).

The energy intensity of the economy and of different sectors decreases. Increased energy efficiency in the residential sector is due to the use of more efficient energy equipment (appliances, lighting, etc.) and buildings, being driven by the Eco-Design regulations and by better thermal integrity of buildings reflecting the Recast of the Energy Performance of Buildings Directive. Energy consumption in transport is decoupling significantly from underlying transport activity growth due to the use of more energy efficient vehicles; this development is largely driven by more fuel efficient cars, in particular hybrids, following the CO2 performance standards set by the CO2 from cars regulation[38].

There is considerable fuel switching in final and primary energy demand in the Reference scenario. In primary energy, the dominance of fossil fuels diminishes with its share falling from 83% and 79% in 1990 and 2005, respectively, to only 64% in 2050. While non fossil fuels (RES and nuclear) account for 36% of primary energy in 2050, they reach a significantly higher share in the 2050 electricity mix. Energy sources not emitting CO2 supply 66% of electricity output in 2050, with 40% RES and 26% nuclear.

Graph 1: Reference scenario- Fuel shares in primary energy



In the CPI scenario, the share of nuclear is lower due to a change in nuclear assumptions. In this new policy environment gas and RES replace nuclear and thereby increase their share over Reference scenario levels.

Power generation

38 Regulation on CO2 from cars 2009/443/EC

The demand for electricity continues rising and there is a considerable shift towards RES with a strong increase in wind. Power generation and capacity from solids decrease throughout the projection period due to increasing carbon prices that reduce the competitiveness of this technology; gas power generation capacity increases, also as peak load activated during back-up periods due to the increased amount of RES in the system. As a result of the large increase in RES in power generation the load factor of the system decreases given the more widespread use of technologies that run only a limited number of hours per year. Investment in power generation increases over the projection period, driven by RES and gas.

The carbon intensity of power generation falls by over 75% in 2050 compared to 2010 levels, driven by the decreasing ETS cap and rising carbon prices. CO2 emissions from power generation decline by 2/3rd between 2010 and 2050, while electricity demand still increases. This strong decarbonisation is brought about by fuel switching to RES and nuclear, an increasing share of gas in fossil fuel generation and significant penetration of CCS after 2030. In 2050 18% of electricity is generated through power plants with CCS (solids and gas).

Electricity demand in the CPI scenario falls well below electricity use in the Reference scenario (by 6.5% in 2030 and 4.3% in 2050), reflecting measures in the Energy Efficiency Plan and the revised Energy Taxation Directive. The CPI scenario takes account of the post Fukushima policy change in Member States, notably the abandonment of the nuclear programme in Italy, and new initiatives, such as the nuclear stress tests that will tend to increase costs for new power plants and retrofitting. The CPI scenario has significantly lower CCS penetration primarily as a result of the ETS price being lower in the longer term and also as a consequence of the relatively moderate progress that has been made since 2009 (Reference scenario) towards the EU objective of having up to 12 large-scale CCS demonstration plants operational by 2015 in Europe.

Table 3: Electricity related indicators in CPI scenario and differences from Reference

	Current Policy Intitiatives				Difference from Reference		
	2005	2020	2030	2050	2020	2030	2050
Gross electricity generation (TWh)	3274	3645	3780	4621	-121	-286	-311
Shares in gross electricity generation					in percentage points		
RES share	14,3%	34,5%	43,6%	48,8%	1,2%	3,1%	8,5%
Nuclear share	30,5%	23,9%	20,7%	20,6%	0,8%	-3,8%	-5,8%
Fossil fuel share	55,2%	41,6%	35,7%	30,6%	-2,0%	0,7%	-2,7%
CCS share	0,0%	0,7%	0,8%	7,6%	-0,6%	-2,1%	-10,2%
Prices in €							
ETS (€(08)/t CO2)	0,0	15,0	32,0	51,0	-2,5	-8,0	1,0
Average electricity price (in €(08)/MWh)	110,1	148,5	159,0	159,9	0,0	1,3	6,1

Heating

A strong increase in demand for distributed steam and heat can be observed between 2005 and 2020 following strong CHP promoting policies, as well as commercial opportunities that arise from gas and biomass based CHP technologies. In the longer term further demand for distributed heat in the tertiary and residential sectors slows down as a result of the trend towards electrification (i.e. heat pumps) and higher energy efficiency which limits the overall demand for heating. In industry the increase in demand for distributed steam is projected to continue in the future because the changes of industrial activity are favourable for sectors with high demand for steam such as chemicals, food, tobacco, and engineering.

In the CPI scenario, demand for distributed heat rises compared to current levels but is 1-2% lower than in the Reference scenario, reflecting the effects of more efficient heating systems used in houses.

Transport

Transport accounts today for over 30% of final energy consumption. In a context of growing demand for transport, final energy demand by transport is projected to increase by 5% by 2030 rising further marginally by 2050. Transport growth is driven mainly by aviation and road freight transport. The EU transport system would remain extremely dependent on the use of fossil fuels. Oil products would still represent 88% of EU transport sector needs in 2030 and 2050 in the Reference scenario.

Energy consumption in transport is little affected by current energy policy initiatives (- 1.7% in 2030 and -5.7% in 2050). Changes from the Reference scenario are brought about in particular by the proposed new energy taxation system and through the somewhat more favourable policy environment for electric and plug-in hybrid vehicles.

Policy relevant indicators (and targets)

Emissions - It is estimated that a continuation of current trends and policies (Reference scenario) would result in 40% reduction in energy-related CO2 emissions between 1990 and 2050 and 26% by 2030. All GHG emissions would fall 40% by 2050 (29% by 2030) which represents about half of the domestic efforts needed by a developed economy in the context of limiting climate change to 2°C[39]. Most emissions continue to be energy related emissions. Carbon intensity falls markedly. Producing one unit of GDP in 2050 would lead to only 21% of energy related CO2 emissions that were required in 1990.

In the CPI scenario emission reductions are broadly similar to those in the Reference scenario. CO2 emissions in 2050 are 41% below 1990 values and below those reached in the Reference case due to greater energy intensity improvements brought about by vigorous energy efficiency policies which overcompensates worsening carbon intensity due to lower availability of nuclear and CCS and lower ETS carbon prices. Total GHG emissions in 2050 decrease by 39% below the 1990 level (1 percentage point less than in the Reference scenario) mainly a result of changes of the carbon price over the next decades.

ETS prices under developments in the Reference scenario rise from 40 € (08)/tCO2 in 2030 to 52 € in 2040 and flattens out to 50 € in 2050. The ETS price in the CPI scenario is lower for most of the projection period reflecting efficiency and RES policies (by about 20% in 2025-2035) and ends at 51 € in 2050.[40]

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39 This includes also some energy-related non-CO2 emissions, e.g. methane emissions from coal mining and losses in gas distribution networks and F-Gas emissions related to air conditioning and refrigeration. While the former are estimated to decrease under current trends, the latter are projected to increase considerably. For a more detailed analysis of the overall GHG reduction efforts needed and of trends in non-CO2 emissions see the Impact Assessment of the Roadmap for moving to a competitive low carbon economy in 2050 (SEC(2011)288).

40 Correspondingly, a higher amount of banking of ETS allowances beyond 2020 takes place in the CPI scenario compared to the Reference scenario, rising from around 2000 Mt to 2700 Mt in 2020 and reducing more slowly in the post-2020 period. For a detailed interplay of ETS, other policies, carbon prices and ETS allowance banking see SEC(2010)650 part 2.

RES target - The Reference scenario assumes that the RES target is reached in 2020; the RES share continues rising in the Reference scenario to reach 24% in 2030 and over 25% in 2050. Further penetration of RES progresses more slowly due to the assumed phasing out of operational aid to mature RES technologies. RES in transport contribute 10% in 2020 to comply with the RES directive; this share increases to 13 % by 2050. However, the pace of electrification in the transport sector is projected to remain slow in the Reference scenario: electric propulsion in road transport does not make significant inroads by 2050[41]. The CPI scenario has higher RES shares, e.g. 25% RES in final energy in 2030 and 29% in 2050.

The indicative 20% energy savings objective for 2020 would not be achieved under current policies - not even by 2050. The Reference scenario would deliver 10% less energy consumed in 2020 compared to the 2007 projections. The CPI scenario delivers significantly more. Energy consumption in 2020 is 14% below the 2007 projections further decreasing significantly up to 2050.[42]

Import dependency - Total energy imports increase by 6% from 2005 to 2050. The increase is rather limited despite decreasing indigenous production, as rising gas (+28% from 2005 to 2050) and biomass imports are compensated by a marked decline in coal imports while oil imports remain broadly stable. Import dependency rises above the present level (54%), reaching 58% in 2020 and flattening out to 2050 thanks to more RES and nuclear. It remains broadly unchanged in the CPI scenario.

Average electricity prices rise up to 2030 and stabilise thereafter. The price increase up to 2030 is due to three main elements: RES supporting policies, ETS carbon price and high fuel prices due to the world recovery after the economic crisis. Thereafter electricity prices remain stable because of the techno-economic improvements of various power generation technologies that limit the effects of higher input fuel prices and CO2 prices. In the CPI scenario, electricity prices are slightly higher (1% in 2030 and 4% in 2050) reflecting the lower share of nuclear as well as higher lifetime extension costs post Fukushima and high investments for new electricity generation capacity, especially RES.

Total costs of energy (including capital costs, energy purchases and direct efficiency investment costs) are rising fast over the projection period but are not equally distributed across sectors. Energy related expenditures in households rise strongly while the growth of energy related costs for services and industry is more moderate. Energy costs are rising faster than GDP and represent around 15.1% of GDP in 2030 (up from 10.5% in 2005) and 14.3% in 2050. The faster rate of growth relative to GDP reflects significant investments needs in energy production, transmission and distribution as well as demand based energy efficiency measures. Under the CPI scenario, system costs are slightly higher amounting to 15.3% and 14.6% in relation to GDP in 2030 and 2050, respectively, reflecting in particular greater investment requirements.

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41 The Reference scenario does not cover the European Commission CARS 21 (Competitive Automotive Regulatory System for the 21st century) initiative and the recent initiatives of car manufacturers as regards electric vehicles.

42 The results diverge slightly from the assessment done for the Energy Efficiency Directive. In fact, measures of the Energy Efficiency Directive were taken but they are expected to produce effects over a longer period of time. Also the stringency of energy efficiency measures is assumed to be slightly lower. However, a more vigorous implementation of the Energy Efficiency Directive is assumed in decarbonisation scenarios which all surpass the indicative 20% target in the decade 2020-2030.

2.4.4. *Sensitivity analysis*

Considering the high degree of uncertainty surrounding projections over such a long time horizon, a sensitivity analysis has been carried out with respect to two key parameters - energy imports prices and GDP. A high and a low case has been analysed for both variables.

<u>GDP</u>
The two economic growth variants explore a High GDP case where GDP per capita is 0.4 percentage points (pp) higher than in the Reference scenario throughout the projection period (+15% increase in GDP level in 2050) and a Low GDP case with GDP per capita 0.4 pp lower (-14.7% in GDP level in 2050). GDP and economic activity have a significant influence on energy consumption in particular in industry and services.

The model based analysis shows that policy relevant indicators are rather insensitive against variations in GDP assumption, which is a significant result given the great uncertainty in making GDP projections for the next few years let alone the next four decades.

CO2 reduction becomes only slightly more difficult to achieve under significantly higher economic growth. Higher economic growth brings more opportunities for innovation and investment leading to improvements in both energy and carbon intensity. In a similar manner, low economic growth entails lower economic activity but fewer investments in low carbon and energy efficient technologies. There is thus only limited further emission reductions brought about by considerably lower GDP levels. RES shares in gross final energy consumption are pretty robust with respect to GDP levels with variation spanning just 1 percentage point in 2050. Import dependency is also unaffected by such significant changes in GDP levels. Policy relevant indicators regarding competitiveness are pretty much unaffected by economic growth; while ETS prices differ to some extent, the effects on electricity prices are marginal.

<u>Energy prices</u>
Two energy price sensitivities were modelled – a High energy price case with the world oil price 28% higher in 2050 and a Low energy price case with the world oil price 34% below the Reference scenario in 2050. In the low price case, fossil fuel import prices remain broadly at the 2010 level; coal prices are stable, oil has a small peak around 2030, whereas gas prices remain weak over the next few years but recover to the 2010 level in the long run.[43]

High world energy prices reduce CO2 and GHG emissions, while low prices exert the opposite influence. However, there are several other effects via the fuel mix, electricity generation, ETS price adaptations with a given cap and CCS incentives that modify the overall effect. In total, differences in world energy prices exert only a minor influence on total GHG emissions in the EU given the existence of the EU ETS with a decreasing cap that is independent from GDP or world energy price developments.

High fossil fuel prices limit business opportunities for energy exporters given that EU imports would decrease, especially for natural gas. Conversely, with lower fossil fuel prices, significantly higher gas deliveries to the EU can be assumed. Import dependency increases with low world energy prices, whereas it stays below the Reference scenario in the High price case. Electricity prices are significantly lower in the Low price case, whereas they are significantly higher in the High energy price case. High energy import prices increase the

[43] Global developments as regards shale gas are taken into account when projecting global gas prices.

EU’s external fuel bill substantially. On the contrary, lower fossil fuel prices give a boost to the EU economy improving its competitiveness, also through lower costs and inflation.

2.4.5. Conclusion

The Reference scenario and CPI assume the overall GHG target, ETS cap and non-ETS national targets to be achieved by 2020 but thereafter GHG reductions fall short of what is required to mitigate climate change with a view to reaching the 2 °C objective. Import dependency, in particular for gas, increases over the projection period and electricity prices and energy costs are rising. So despite efforts over recent years, the long term effects of our current and planned policies are not sufficient to achieve the ambitious decarbonisation objective and to improve both security of supply and competitiveness. These conclusions are broadly consistent with other major stakeholder work such as the IEA World Energy Outlook 2010 (Current Policies scenario), the European Climate Foundation (baseline scenario); Power Choices (baseline scenario) and Greenpeace (baseline scenario). A more thorough comparison of stakeholder work is provided in Annex 2.

2.5. The EU's right to act and EU added-value

The EU's competence in the area of energy is set out in the Treaty on the Functioning of the European Union, in Article 194[44]. EU competences related to combating climate change, including GHG emission reductions in energy and other sectors, are enshrined in Art. 191-193. The EU's role needs to respect the principles of subsidiarity and proportionality.

From an economic perspective, as is the case with the European carbon market, many energy system developments can best be achieved on an EU-wide basis, encompassing both EU and Member State action while respecting their respective competences. An EU wide European market can facilitate the balancing of the electricity system, reduce the need for back-up capacities and encourage RES production where it economically makes most sense. Large scale investments require big markets which also justify one EU wide approach. A bigger market can also better encourage the development of innovative products and systems mainly in the area of energy efficiency and renewables.

2.6. Who is affected?

Everybody is affected. Energy consumers will be affected by higher energy costs (a combination of energy prices and amount of energy used) as well as by extra non-energy investment needed such as more efficient appliances, new types of vehicles, house renovations, etc. The energy industry will be directly concerned as it needs to heavily invest in the next two decades. Public authorities will also need to engage in discussions about the pros, cons and trade-offs of different options as each generation source has its drawbacks (solar and wind generation will require significant infrastructure investments; supply of sustainable biomass might be limited; nuclear faces public acceptance and waste problems

[44] Article 194:
1. In the context of the establishment and functioning of the internal market and with regard for the need to preserve and improve the environment, Union policy on energy shall aim, in a spirit of solidarity between Member States, to:
(a) ensure the functioning of the energy market;
(b) ensure security of energy supply in the Union;
(c) promote energy efficiency and energy saving and the development of new and renewable forms of energy;
(d) promote the interconnection of energy networks.

and CCS still requires large-scale experience to be able to reduce costs and sufficiently decrease financial risks for private investors). Changes in the EU energy sector will also have a strong influence on third countries, notably fuel suppliers.

3. SECTION 3: OBJECTIVES

3.1. General objective

The general objective is to shape a vision and strategy of how the EU energy system can be decarbonised by 2050 while taking into account the security of supply and competitiveness objectives.

3.2. Specific objectives

To achieve the general objective, more specific objectives are being proposed:

– Assist political decision making for providing more certainty to investors as regards possible future policy orientations at the EU level by showing different decarbonisation pathways to 2050 as well as their main economic, social and environmental impacts;

– Show trade-offs among policy objectives as well as among different decarbonisation pathways and identify common elements in all decarbonisation pathways;

– Help policy makers set milestones after 2020.

The Roadmap 2050 should be based on the current key objectives of EU energy policy – sustainability, security of supply and competitiveness. Not all three objectives can be specified and quantified in the same manner. While the decarbonisation objective can be relatively easily defined and quantified, the other two are more complex. The goal of sustainability is linked in particular to the achievement of 80% domestic GHG reduction below 1990 in 2050, which implies a reduction of energy related CO2 emissions by 85%, consistent with the required contribution of developed countries as a group to limit global climate change to a temperature increase of 2ºC compared to pre-industrial levels. The goal of security of supply entails not only decreasing import dependency but also increasing supply diversity and continued stability of electricity grid. The competitiveness objective implies assuring a competitive energy sector, encouraging investments and achieving affordable energy costs for consumers as well as developing new technologies and ensuring a competitive clean technology manufacturing sector.

In general the objectives of energy policy are complementary and mutually reinforcing. For example, increased energy efficiency reduces GHG emissions, increases energy security and contributes towards achieving a competitive energy sector. A significant part of low carbon energy supply can be produced in the EU, thus also increasing energy security of supply. However, there are also some possible **trade-offs**. Some of them are presented below for illustration:

– Renewables do not require fuels to be imported and emit less or no GHG emissions, but may need public support (if necessary and proportionate) to be competitive; this increases costs to consumers. The merit order effect however reduces wholesale electricity prices.

– Although nuclear is a large provider of low carbon electricity in the EU, it faces in some MS acceptance and financing problems.

– CCS prevents CO2 emissions, but is comparatively resource inefficient in relation to unabated fossil fuel combustion. Up to 25% additional energy input may be needed for capture, transport and storage of CO2.
– Gas is the fossil fuel with the lowest carbon content but poses a challenge to security of supply especially for countries with undiversified supplies.
– The current tariff-setting for transmission and distribution networks is cost-based and should assure the lowest short term prices to consumers but is not yet supportive enough to new technologies enabling integration of RES and energy efficiency that have longer term benefits.

3.3. Consistency with other European policies

The Energy Roadmap 2050 subscribes into the overall framework of decarbonisation as designed by the flagship initiative Resource efficient Europe and the Roadmap for moving to a competitive low carbon economy in 2050. All objectives are coherent with the objectives of the medium term strategy as described in the Communication Europe 2020 and Energy 2020 as well as with energy policy objectives as described in the Lisbon Treaty.

4. SECTION 4: POLICY OPTIONS

4.1. Methodology

This is not a typical impact assessment in that it does not list policy options to meet certain policy objectives and then assesses impacts of these policy options to determine a preferable one. It rather examines a set of possible alternative future developments to get more robust information on how the energy system could achieve 85% reduction of energy related CO2 emissions compared to 1990 without selecting one of them as the preferred option. Nor does it seek to justify the decarbonisation target as this was the focus of the Low Carbon Economy Roadmap[45] . It is mainly concerned with analysing possible energy related pathways to reach decarbonisation in a "global climate action" world. **Lower import fossil fuel prices are introduced to reflect significant impacts on global fossil fuels prices in policy scenarios** while fossil fuel prices are higher in the Reference scenario and CPI scenarios which project current trends and policies[46].

The Energy Roadmap assumes the implementation of the European Council's decarbonisation objective that includes similar efforts by industrialised countries as a group. The analysis presented focuses on energy consequences. A more comprehensive analysis of different global paths to decarbonisation was presented in the Low Carbon Economy Roadmap 2050[47], exploring the impacts of three global climate situations: a) business as usual; b) global climate action and c) fragmented action. Fragmented action assumes strong EU climate action that is however followed globally only by the low end of the Copenhagen pledges up to 2020 and afterwards the ambition level of the pledges is assumed to stay constant. It analyses impacts on energy intensive industries (EII) both in a global macroeconomic modelling framework to address carbon leakage issues and by means of energy system modelling to address the effects of fragmented action, including electricity costs for companies. Electricity costs are, in fact, higher in the fragmented action scenarios as compared to the global action scenarios due to

45 COM (2011)112
46 Please see IA on Low carbon economy Roadmap for the analysis of impacts of decarbonisation on energy import prices SEC(2011)288.
47 Impact assessment report SEC(2011)288 final, section 5)

higher energy import prices. On the other hand, carbon prices are lower under fragmented action.

A "fragmented" action scenario including measures against carbon leakage was not analysed in this IA report as the challenges for the energy sector arising from decarbonisation are the biggest under the "global climate action" assumption, given that fragmented action with measures against carbon leakage will deliver lower GHG reductions by 2050. Decarbonisation scenarios that accommodate action against carbon leakage under fragmented action could either go for lower ambitions in terms of GHG reduction for sectors with relevant leakage risks or could have measures included that compensate efforts for energy intensive industries. With action on carbon leakage the challenge for the transition in the energy system could be smaller given lower efforts in parts of the system. Such results are however modified through countervailing effects from lower world fossil fuel prices under global action that encourage somewhat higher energy consumption and emissions. In any case, the implementation of measures will be crucial. The real difference for industrial and thereby climate policy might come from the concrete design of policy instruments that is not discussed in this the Energy Roadmap Impact Assessment (e.g. special provisions on ETS for EII).

Section 5 provides an assessment of the environmental, economic and social impacts that is proportionate to the nature of the document proposed. The assessment is supported by modelling results and/or by academic research where possible. It is important to underline that modelling results are tentative and present impacts as illustrations rather than as conclusive evidence. A 40-year outlook is naturally steeped in uncertainty. Whereas some parameters such as population growth can be projected with a reasonable degree of confidence, the projection of other key factors such as economic growth, energy prices or technological developments over such a long time span incorporates a great deal of uncertainty.

The modelling framework used for decarbonisation scenarios is the same as for the Reference scenario (see section 2.4 and annex 1). A quantitative methodology is the core of this assessment. However, not all aspects could be modelled. For instance, significant environmental impacts that go beyond GHG emissions, such as impacts on biodiversity and air pollution, were not assessed quantitatively. For GDP and employment impacts, analysis done for the Communication on moving beyond 20% GHG reductions[48] and several recent studies were used. It was neither possible to assess impacts on different household income levels, nor distributional impacts at Member State level.

The methodology factors in uncertainties but ensures for a coherent approach based on proven technologies, applying the following limitations:

– Taking into account existing physical and capital infrastructure and limitations regarding physical and capital stock turn-over.
– Technological progress over time is assumed as typical in long term modelling. Potential break-through technologies depending on unforeseeable structural change have not been taken into account. Similarly, major lifestyle changes, beyond demand side effects of carbon pricing on behaviour, have not been taken into account in

48 European Commission: Communication 'Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage' (COM(2010) 265 final). Background information and analysis, Part II (SEC(2010) 650).; http://ec.europa.eu/clima/documentation/international/docs/26-05-2010working_doc2_en.pdf

quantitative terms, as this goes beyond the capabilities of the quantitative modelling tools.[49]

– The modelling also could not take into account effects of the changing climate itself on the energy system. Effects can go in different directions and will depend on how climate changes in different parts of the EU (e.g. more demand for cooling, less demand for heating, impact on water availability for power plant cooling or hydroelectricity production).

Only by comparing results from different decarbonisation scenarios is it possible to extract more robust conclusions, how key parameters influence the results and how various parts interact with each other. By requiring similar levels of cumulative GHG emissions across scenarios, this analysis ensures comparability, as regards the objective of decarbonisation, given that emission mitigation aims at preventing dangerous levels of atmospheric GHG concentrations that is a matter of cumulative emissions. An identification of common features to all scenarios will be an important part of the analysis. The Commission's own scenario analysis will be complemented by MS and other stakeholders' work. An in-depth impact assessment report examining impacts of concrete policy measures will be submitted for any legislative proposal following this roadmap.

4.2. Policy options

Several useful scenarios could be proposed for a decarbonisation analysis of the energy system. The design of scenarios was extensively discussed with various stakeholders. Stakeholders and the European Commission identified four main decarbonisation routes for the energy sector – energy efficiency impacting mostly on the demand side and RES, nuclear and CCS predominantly on the supply side (lowering the carbon intensity of supply). This finding is in line with the decarbonisation scenarios of a number of stakeholders, such as Eurelectric Power Choices, the Energy Roadmap of the European Climate Foundation and the work done at national level by some MS (such as the UK, DE and DK). The policy options (scenarios) proposed explore five different combinations of the four decarbonisation routes. Decarbonisation routes are never explored in isolation as the interaction of different elements will necessarily be included in any scenario that evaluates the entire energy system.

All decarbonisation scenarios achieve close to 85% energy related CO2 emissions by 2050 and it is carefully assessed what effect each policy option has in terms of security of supply, competitiveness of the energy sector and affordability of energy costs. All scenarios use the same assumptions about GDP developments as the Reference scenario. The scenarios achieving the European Council's GHG objective have lower fossil fuel prices as a result of lower global demand for fossil fuels reflecting worldwide carbon policies (oil price is 84 USD'08 per bbl in 2020; 79 in 2030 and 70 in 2050). In addition, most technology assumptions are the same as in the Reference scenario, although there are additional features and mechanisms to stimulate decarbonisation and technology penetration. For details please see Annex 1, pages 56-60.

Table 4: Policy options/Scenarios

	Option/scenario	Short description
1	**Business as usual (Reference**	The Reference scenario includes current trends and long-term projections on economic development (GDP growth 1.7% pa). It takes into account rising fossil

[49] For details and the implications on the cost and benefit quantifications please refer to Annex 1, part A, point 1.4 and part B, points 1.4 and 2.7·

	scenario[50])	fuel prices and includes policies implemented by March 2010. The 2020 targets for GHG reductions and RES shares will be achieved but no further policies and targets after 2020 (besides the ETS directive) are modelled. See also section 2.4 Sensitivities: a) a case with higher GDP growth rates, b) a case with lower GDP growth rates, c) a case with higher energy import prices, d) a case with lower energy import prices.
1bis	**Current Policy Initiatives – CPI scenario (updated Reference scenario)**	The Reference scenario includes only adopted policies by March 2010. Since then, several new initiatives were adopted or are being proposed by the EC. The EC outlined its future work programme on energy mainly until 2020 in the Communication "Energy 2020 - A strategy for competitive, sustainable and secure energy". This policy option analyses the extent to which measures adopted and proposed will achieve the energy policy objectives.[51] It includes additional measures in the area of energy efficiency, infrastructure, internal market, nuclear, energy taxation and transport. Technology assumptions for nuclear were revised reflecting the impact of Fukushima and the latest information on the state of play of CCS projects and policies were included. See also section 2.4.
	Decarbonisation scenarios	All decarbonisation scenarios build on Current Policy Initiatives (reflecting measures up to 2020) and are driven by carbon pricing to reach some 85% energy related CO2 reductions by 2050 (40% by 2030) which is consistent with the 80% reduction of GHG emissions. Transport measures (energy efficiency standards, low carbon fuels, infrastructure, pricing and transport planning) as reflected in the Transport White Paper are included in all scenarios. All scenarios will reflect significant development of electrical storage and interconnections (with the highest requirements in the High RES scenario). Different fuels can compete on a market basis besides constraints for nuclear investment in scenario 6.
2	**High Energy Efficiency**	This scenario is driven by a political commitment of very high primary energy savings by 2050 and includes a very stringent implementation of the Energy Efficiency plan. It includes further and more stringent minimum requirements for appliances and new buildings; energy generation, transmission and distribution; high renovation rates for existing buildings; the establishment of energy savings obligations on energy utilities; the full roll-out of smart grids, smart metering and significant and highly decentralised RES generation to build on synergies with energy efficiency.
3	**Diversified supply technologies[52]**	This scenario shows a decarbonisation pathway where all energy sources can compete on a market basis with no specific support measures for energy efficiency and renewables and assumes acceptance of nuclear and CCS as well as solution of the nuclear waste issue. It displays significant penetration of CCS and nuclear as they necessitate large scale investments and does not include additional targeted measures besides carbon prices.
4	**High RES**	The High RES scenario aims at achieving a higher overall RES share and very high RES penetration in power generation, mainly relying on domestic supply[53].
5	**Delayed CCS**	This scenario follows a similar approach to the Diversified supply technologies scenario but assumes difficulties for CCS regarding storage sites and transport while having the same conditions for nuclear as scenario 3. It displays considerable penetration of nuclear.
6	**Low nuclear**	This scenario follows a similar approach to the Diversified supply technologies scenario but assumes that public perception of nuclear safety remains low and that implementation of technical solutions to waste management remains unsolved leading to a lack of public acceptance. Same conditions for CCS as scenario 3. It displays considerable penetration of CCS.

50 Used also in the Low Carbon Economy Roadmap and Transport White Paper.

51 This analysis does not prejudge the final outcome of the legislation process on these policies and will not be able to deliver a quantitative assessment of the consequences of the Energy 2020 strategy.

52 Scenario 3 reproduces "Effective and Widely Accepted Technologies" scenario used in Low Carbon Economy roadmap and Transport White Paper on the basis of scenario 1bis.

53 Global climate action requires that each region uses its RES potential. Moreover, geopolitical and security of supply risks can justify the reliance on domestic energy sources.

A more detailed presentation of assumptions for all scenarios can be found in Annex 1.

5. SECTION 5: ANALYSIS OF IMPACTS

5.1. Environmental impacts

Energy consumption and use of renewable energy

Primary energy consumption is significantly lower in all decarbonisation scenarios as compared to the Reference scenario. The biggest decline of primary energy consumption comes in the High Energy Efficiency scenario (-16% in 2030 and -38% in 2050) showing the effects of stringent energy efficiency policies and smart grid deployment. The decrease in energy consumption compared with the Reference scenario for all decarbonisation scenarios spans a range from 11-16% in 2030 and 30-38% in 2050. Compared with primary energy consumption in 2005 there is a very significant decrease of 32-41%. It is important to note that these levels of reduced primary energy demand do not come from reduced GDP or sectoral production levels (which remain the same in all scenarios). Instead they are mainly the result of technological changes on the demand and supply side, coming from more efficient buildings, appliances, heating systems and vehicles and from electrification in transport and heating. All decarbonisation scenarios over-achieve the 20% energy saving objective in the decade 2020-2030[54]. This result is consistent with other stakeholder work.

Not only the amount, but also the composition of energy mix would differ significantly in a decarbonised energy system. Low carbon energy sources are strongly encouraged but can follow various decarbonisation routes shown by rather wide ranges for shares of energy sources in primary energy while all satisfying the decarbonisation requirement by 2050. Moreover, all decarbonisation routes achieve the same cumulative GHG emissions in 2011-2050.

Table 5: Fuel shares in primary energy consumption

		Reference/CPI		**Decarbonisation scenarios**	
	2005	2030	2050	2030	2050
RES	6,8%	18,4%-19,3%	19,9% - 23,3%	21,9% - 25,6%	40,8% - 59,6%
Nuclear	14,1%	12.1% - 14,3%	13,5% - 16,7%	8.4% - 13,2%	2,6% - 17,5%
Gas	24,4%	22,2% - 22,7%	20,4% - 21,9%	23,4% - 25,2%	18,6% - 25,9%
Oil	37,1%	32,8% - 34,1%	31,8% - 32,0%	33,4% - 34,4%	14,1% - 15,5%
Solid fuels	17,5%	12,0% -12,4%	9,4% - 11,4%	7,2% - 9,1%	2,1% - 10,2%

54 The scenarios are based on model assumptions, which are consistent with the input for the 2050 Low Carbon Economy Roadmap. Recognising the magnitude of the decarbonisation challenge, which implies a reversal of a secular trend towards ever increasing energy consumption, this Energy Roadmap has adopted a rather conservative approach as regards the effectiveness of policy instruments in terms of behavioural change. However, the Roadmap results should not be read as implying that the 20% energy efficiency target for 2020 cannot be reached effectively. Greater effects of the Energy Efficiency Plan are possible if the Energy Efficiency Directive is adopted swiftly and completely, followed up by vigorous implementation and marked change in the energy consumption decision making of individuals and companies. In modelling terms this means a significant lowering of the discount rate used in energy consumption decision making of hundreds of millions of consumers.

Renewables increase their share in primary energy substantially in all decarbonisation scenarios to reach at least 22% by 2030 and at least 41% by 2050. The RES share in primary energy is the highest in the High RES scenario (60% in 2050). The RES share is higher when calculated in terms of gross final energy consumption[55]- it represents at least 28% (2030) and 55% (2050) in all decarbonisation scenarios and rises up to 75% in 2050 in the High RES scenario. The share of renewables in power generation stands at 86% in 2050 in the High RES scenario and the share in power *consumption* is even higher at 97% in 2050.[56] RES share in power generation can be further increased by allowing for imports of renewable electricity from North Africa.

Nuclear developments have been affected by the policy reaction in some Member States after the nuclear accident in Fukushima. The share of nuclear varies depending on policy assumptions. In the Low nuclear scenario the nuclear share declines gradually to 3% by 2050. In the most ambitious nuclear scenario (Delayed CCS scenario), the share rises to 18%.

The share of gas is higher in the Current Policy Initiatives scenario compared to the Reference scenario, partly replacing nuclear. It increases slightly by 2050 in the Low nuclear scenario where the CCS share in power generation is around 32%. The oil share declines only slightly until 2030 due to the high dependency of transport on oil. However, the decline is significant in the last decade (2040-2050) when oil in transport is to a large extent replaced by biofuels and electricity. The share of solid fuels shrinks further to reach only 2-6% in all decarbonisation scenarios except in the Low nuclear scenario (10% in 2050).

Final energy demand declines similarly to primary energy demand. In the High Energy Efficiency scenario the reduction compared to the Reference scenario is -14% in 2030 and -40% in 2050. The decrease in the decarbonisation scenarios is at least -8% in 2030 and -34% in 2050. Sectors showing higher reductions than the average are residential, tertiary and generally also transport. There is a lot of structural change in the fuel composition of final energy demand. Given that it is highly efficient and emission free at use, electricity makes major inroads already under Current Policy Initiatives (increase by 9 pp in 2005-2050). The electricity share soars further in the decarbonisation scenarios reaching 36% - 39% in 2050 (almost doubling from current levels and becoming the most import final energy source), reflecting also its important role in decarbonising heating and transport. The crucial issue for any decarbonisation strategy is therefore the full decarbonisation of power generation.

Energy intensity reduces by at least 67% in the Delayed CCS scenario (2005-2050). It reduces by 70% in the High RES and Low nuclear scenarios and by 71% in the Energy Efficiency scenario in 2005-2050 (against a 53% improvement in the Reference scenario).

Emissions

All decarbonisation scenarios achieve 80% GHG reduction and close to 85% energy related CO2 reductions in 2050 compared to 1990 as well as equal cumulative emissions over the projection period. In 2030, energy-related CO2 emissions are between 38-41% lower, and total GHG emissions reductions are lower by 40-42%.

[55] As specified in the RES directive for the calculation of the 20% target by 2020.

[56] With much more variable supply and demand some electricity produced needs to be stored. Losses, linked to storage, lead to lower consumption than production of electricity. When calculating the RES-E share in line with the RES directive (focussing on gross final energy consumption i.e. excluding energy losses to pumped storage and hydrogen storage), the RES share in electricity consumption amounts to 97%.

Impacts on biodiversity, air pollution and other environmental impacts
The ranking of the different policy options as regards impacts on biodiversity, air pollution, water use and other environmental impacts depends on the implementation of different energy mixes. Some overall trends are presented below while some impacts are analysed in the Resource Efficiency Roadmap 2050 but with much less focus on energy.

In most scenarios, air pollution can be expected to decrease significantly, as this often goes hand in hand with GHG emissions. However, in some cases (especially if the energy mix leads to the development of small unregulated biomass plants), particulate matter (PM) and gaseous emissions could rise, causing local air pollution and regional acidification issues, although the overall effects can be expected to remain positive[57].

All options will impact land use and consequently biodiversity and other land-related ecosystem services. Indeed, any new infrastructure, be it in terms of grid development, power plant installations (nuclear, CCS, fossil), renewable infrastructure (sitting of wind mills, hydropower dams) will lead to land use changes and fragmentation, with potential negative impacts on biodiversity and on the services we receive from ecosystems. However, if the infrastructure development follows well established environmental rules, these potentially negative consequences can be limited[58]. Therefore, the pathways as such do not necessarily lead to land use and biodiversity problems, as this will depend on implementation. Consequences of mostly domestic RES are presented in terms of needs for domestic biomass[59] giving details for each scenario on the total use of biomass and biofuels in transport). The maximum amount of biofuels in 2050 would reach 300 Mtoe for use within the EU and 20 Mtoe for bunkers. The other decarbonisation scenarios have around 270 Mtoe including bunkers.[60] Still, there are also impacts of CO2 emissions related to land use, land use change and forestry due to increased bioenergy use.[61] As the biomass needed for energy will not only come from forests/forest-based industries, biowaste and residues, this will require considerable additional amounts of agricultural land.

In terms of water use, the consequences will depend on the energy mix. New hydropower projects (including pumped storage), the cultivation of some energy crops, and increased demand for water for cooling in the nuclear energy sector might exacerbate existing water shortages, increasing potential impacts on river morphology and groundwater availability, all this in a context of increasing EU temperatures and reduced water availability.

5.2. Economic impacts

Economic growth
The current report is part of a joint Commission analysis related to the transition to a low-carbon economy by 2050. Previous assessment by the Commission shows that the costs by

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57 For a detailed analysis see SEC(2011)288, section 5.2.14.

58 For example by making sure that rich habitats are not fragmented, ensuring the integrity of Natura 2000 sites and the coherence and connectivity of its network. Green Infrastructure developments can lead to win-win situations, where negative environmental impacts of energy-related infrastructure can be mitigated while adaptation to climate change is enhanced, as well as public acceptance of alternative energy projects.

59 Annex 1, table 37, pages 83

60 The European Environment Agency assessed the amount of biomass that could be used in an environmental sustainable way in EU-25 by 2030 at 295 Mtoe·

61 ·For a detailed analysis of these interactions see SEC(2011)288, sections 5.1.4, 5.2.7 and 5.2.10.

2020 of putting the EU economy on a path that meets the long-term requirements for limiting climate change to 2°C would be limited compared to business-as usual, at around 0.2%-0.5% of GDP[62], with access to international carbon credits. Using the additional revenues from auctioning CO2 emissions allowances in EU ETS sectors and tax revenues from the non-ETS sectors to decrease labour costs would improve overall macroeconomic results leading to 0.4%-0.6% increase in GDP by 2020.

As regards the differentiated impact of policy options on economic growth, the long-term perspective implies that it is very difficult to go beyond a qualitative assessment. The Reference and CPI scenarios have higher fuel costs which do not generate much economic growth but require fewer investments in new technologies. On the contrary, the decarbonisation scenarios entail much higher investment in equipment and energy efficiency while lowering expenditure on fuels. These investments can generate further GDP growth and technologies may be exported worldwide if the EU keeps its front-runner position. Thus, policy scenarios which drive forward energy efficiency measures and investments in renewable energy technology have the potential to generate new industries, jobs and substantial economic growth. Although it is difficult to assess in details, such investments could also protect the EU economy against external energy price shocks[63].

An assessment of the macro-economic impact of the European decarbonisation objectives towards 2050 was performed in the European Climate Foundation's 2050 Roadmap[64]. It shows an annual GDP growth of 0.1% below the baseline scenario until 2015 but a reversal of the trend afterwards resulting in GDP being 2% above the baseline in 2050. Marginally positive effects remain under different sensitivity cases.

Energy system costs

The **total energy system costs** are costs for the entire energy system including capital cost, (for energy using equipment, appliances and vehicles), fuel and electricity costs, and direct efficiency investment costs (house insulation, control systems, energy management, etc) [65]. They exclude disutility costs[66] and auction payments[67].

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62 SEC(2010) 650, Commission Staff Working Document accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage: Background information and analysis.

63 For further analysis of the role of energy price shocks see SEC(2011)288.

64 "Roadmap 2050: a practical guide to a prosperous, low-carbon Europe; Volume 1 – Technical and Economic Analysis" (European Climate Foundation, 2009)

65 As discussed in Annex 1, this represents a cautious approach. Whereas investment costs are displayed at their actual maximum levels, future benefits are priced in at a lower level.

66 Disutility costs are a concept that captures losses in utility from adaptations of individuals to policy impulses or other influences through changing behaviour and energy consumption patterns that might bring them on a lower level in their utility function. The PRIMES model has a micro-economic foundation which allows it to deal with utility maximisation and to calculate such perceived utility losses via the concept of compensating variations. While these costs capture relevant short term transition costs, their relevance and appropriate calculation over a long time horizon is challenging. This concept has to assume that preferences and values remain the same, even over 40 years, and it compares utility with a hypothetical state of no policy or no change in framework conditions. Examples of such decreases in utility are lowering thermostat in space heating, reducing cooling services in offices, switching lights off, staying at home instead of travelling, using a bicycle instead of a car, etc.

67 Auction payments are expenditures for individual sectors, and are not considered as costs for the economy as a whole, since the auctioning revenues are assumed to be recycled back into the economy in a neutral way. However, one could also have taken account of the shadow costs in making public

Table 6: Average annual total energy system cost (without auctioning and disutility)

Average annual total energy system costs 2011-2050

Bln. EUR'08	**Ref**	**CPI**	**High Energy effic.**	**Div. supply techn.**	**High RES**	**Delayed CCS**	**Low nuclear**
Capital cost	955	995	1115	1100	1089	1094	1104
Energy purchases	1622	1611	1220	1295	1355	1297	1311
Direct efficiency inv. costs	28	36	295	160	164	161	161
Total cost for final consumers excl. all auction payments and disutility	2582	2619	2615	2535	2590	2525	2552

Absolute Difference to Reference

Bln. EUR'08	**High Energy effic.**	**Div. supply techn.**	**High RES**	**Delayed CCS**	**Low nuclear**
Δ Capital cost	160	145	134	139	149
Δ Energy purchases	-402	-327	-267	-325	-312
Δ Direct efficiency inv. costs	267	132	135	133	133
Δ Total cost for final consumers excl. all auction payments and disutility	33	-47	8	-57	-29

Depending on the decarbonisation scenario, there are no or little additional average annual energy system costs due to the pursuit of major decarbonisation as part of a global effort compared with the Reference and CPI scenarios. Diversified supply technologies and Delayed CCS scenarios have the lowest level of average annual energy system costs, representing even a cost saving of around 90 bn €(08) compared with CPI (around 50bn € compared to the Reference scenario) mainly due to large fossil fuel import savings. Those two scenarios have the highest nuclear share[68].

The modelling results suggest that the highest total energy system costs will occur in the High Energy Efficiency scenario. Unlike the majority of other scenarios, the modelling of the High Energy Efficiency scenario does not rely entirely on economic optimisation in determining the level of energy consumption, but rather projects the impact of a set of energy efficiency measures (building retrofit etc.). In addition, the scenario pushes the limits of what the chosen measures can achieve (by assuming that the whole European building stock is fully refurbished; by making use of distributed renewable energy solutions as one of the more expensive renewable energy solutions; by amortising long-lived measures over a short time). Furthermore, it has to be taken into account that all policy scenarios already include considerable energy efficiency improvements and the cost difference merely indicates an

transfers and it is not guaranteed that this transfer would be purely neutral for the economy, as shown by the discussions on the optimal reallocation of auction revenues (see above).

68 When taking a macroeconomic view, i.e. by excluding auctioning revenue that are recycled to the economy, and excluding disutility costs, the Delayed CCS scenario has lower costs than the Diversified supply technologies scenario. However, when the economic actors' perspective is taken, i.e. auctioning and disutility costs are included, the lowest system costs materialise in the Diversified supply technology scenario (for details see Annex 1, part B, point 2.7).

increasing marginal cost for moving from a high to a very high level of energy efficiency (see Annex 1, part B for details). Finally, the modelling reflects significant transaction costs for energy efficiency investments in the form of relatively high weighted average costs of capital.

Cumulative auction payments are lowest in the High Energy Efficiency scenario due to the reduced energy consumption, decreasing emissions and therefore the necessity to buy ETS permits. The scenario with the highest auction revenues is Delayed CCS where the delay in the use of CCS leads to high carbon prices to ensure the achievement of the decarbonisation target in later years, which is made more challenging by the fact that CCS has not been able to move down the cost curve earlier. The auction revenues represent an equivalent of around 1% of total cumulative energy system costs.

All scenarios show higher annual costs in the last two decades 2031-2050 reflecting mainly increased investments in transport equipment as the major transition to electric and plug in hybrids vehicles is projected after 2030. In the High RES scenario costs are also linked to significant expansion of RES based power generation capacity.

The **ratio of energy system costs to GDP** is similar across the scenarios: ranging from around 14.1% to 14.6%, the costs of the Diversified supply technologies and delayed CCS scenarios being at the lower end of the range.

Table 7: Cumulative system costs related to GDP 2011-2050

	Cumulative system costs related to GDP
Reference	14.37%
CPI	14.58%
High Energy Efficiency	14.56%
Diversified supply technologies	14.11%
High RES	14.42%
Delayed CCS	14.06%
Low nuclear	14.21%

The **external fuel bill** arising from the net imports of fossil fuels decreases below 2005 levels in all decarbonisation scenarios by 2050. This result stems from the pursuit of major decarbonisation as part of a global climate effort with fossil fuel import prices expected to be much lower. The actual imports of fossil fuel due to energy efficiency and penetration of RES will be much lower too. These combined effects reduce the expenditure for each fossil fuel and thereby the total external fuel bill of the EU. The decrease of the fuel bill from 2005 in the decarbonisation scenarios is smallest in the Low nuclear scenario at 31% and highest in the High RES scenario at 43% with RES replacing most fossil fuels. Compared with the current level, all decarbonisation scenarios increase their fuel bill in 2030, but to much lower levels than the Reference and CPI scenarios. Savings in the external fuel bill are most striking in 2050. Compared with the CPI scenario, the EU economy could save in 2050 between 518 and 550 bn € (08) by taking this strong decarbonisation route under global climate action.

Impacts on competitiveness

Average prices of electricity are rising compared to 2005 in all scenarios including Reference and CPI scenarios (by a range of 41% in the High Energy Efficiency scenario to 54% in the Low nuclear scenario in 2030 and by 34% in the Diversified supply technologies to 82% in the High RES scenarios in 2050). Electricity prices are calculated in such a way that total costs of power generation, balancing, transmission and distribution are recovered, ensuring that investments can be financed. The residential sector has the highest user price and industry the lowest as is currently the case. Decarbonisation scenarios have lower fuel costs but tend to have higher capital investment costs that offer more business opportunities for domestic investments instead of fuel imports.

Due to depressed demand for electricity, the High Energy Efficiency scenario shows the lowest prices in 2030 for all sectors – even slightly lower than in the Reference scenario (which however exhibits a significant price increase from today's level). In 2050, electricity prices are lowest in the Diversified supply technologies scenario for all sectors, except industry, which faces slightly higher prices compared with the Reference and Current Policy Initiatives. In 2050, average electricity costs are highest in the High RES scenario while the Low nuclear scenario has the highest prices in 2030.

In this exercise, potential macroeconomic benefits from the development of "green technology" manufacturing and services sectors have not been quantified for the various policy scenarios.

Energy related costs for companies

Electricity prices for industry are the lowest among all sectors. The lowest increase occurs in the Diversified supply and Delayed CCS scenarios and the highest increase, similarly to average prices developments, in the High RES scenario. As the whole analysis is performed under the hypothesis of "global climate action", the whole world would decarbonise and would have to bear carbon prices, so the question of industrial competitiveness would not arise. More information on electricity costs is provided in Annex 1 (part B, point 2.7). If no global climate deal is reached and the EU is reducing emissions significantly more than other countries, certain industries supplying low carbon technologies will benefit from improved competitiveness due to higher internal demand and first mover advantage. However, for energy intensive industries it would be difficult to realise the prescribed GHG reductions without affecting their international competitiveness through higher carbon, fuel and electricity prices. This might be even more pronounced if reductions need to be achieved with CCS, which is a technology that has no other benefits than reducing GHG emissions.

Energy related costs in relation to sectoral value added rise from 5.8% in 2005 to 7.8% in 2030 in the Reference/CPI cases and to around 7.5% in the decarbonisation scenarios. In 2050, under current policies, this indicator declines to 7.5% and even more so in the decarbonisation scenarios falling to less than 7%.

Energy intensive industries face particularly high energy costs for their highly energy consuming production processes. Energy related costs in relation to sectoral value added for five industrial sectors (iron and steel, non-ferrous metals, non metallic mineral products, chemicals, paper and pulp industries) would rise under current trends, but would be markedly lower under global decarbonisation. Following lower world energy prices and due to energy efficiency improvements, the ratio of energy costs to value added would return to the 2005 level by 2050 in most decarbonisation scenarios, except for the Energy Efficiency scenario, which exhibits an even lower ratio.

ETS carbon prices

The ETS allowance price rises moderately from the current level until 2030 and significantly in the last two decades providing support to all low carbon technologies and energy efficiency. After 2020, the same carbon value applies also to non- ETS sectors assuring cost-efficient emissions abatement in the whole economy post 2020. Concrete policy measures such as those pushing energy efficiency and/or those enabling penetration of renewables depress demand for ETS allowances which subsequently lead to lower carbon prices. Carbon prices are the lowest in the High Energy Efficiency scenario with lowest energy demand followed by the High RES scenario (in 2030 and 2040) and Diversified supply technologies[69] (in 2050). Delay in penetration of technologies (CCS) or unavailability of one decarbonisation option (nuclear) put an upwards pressure on demand for allowances and ETS prices.

Table 8: ETS prices in €'08/t CO2

	2020	2030	2040	2050
Reference	18	40	52	50
CPI	15	32	49	51
High Energy Efficiency	15	25	87	234
Diversified supply technologies	25	52	95	265
High RES	25	35	92	285
Delayed CCS	25	55	190	270
Low nuclear	20	63	100	310

Impacts on infrastructure

Infrastructure[70] requirements differ between scenarios. Decarbonisation scenarios require increasingly more sophisticated infrastructures (mainly electricity lines, smart grids and storage) than Reference and CPI scenarios. The High RES scenario necessitates additional DC lines mainly to transport wind electricity from the North Sea to the centre of Europe and more storage.

Table 9: Grid investment costs (investments in transmission grid including interconnectors and investments in distribution grid including smart components).

(Bln Euro '05)	2011-2020	2021-2030	2031-2050	2011-2050
Reference	292	316	662	1269
CPI	293	291	774	1357
High Energy Efficiency	305	352	861	1518
Diversified supply technologies	337	416	959	1712
High RES	336	536	1323	2195
Delayed CCS	336	420	961	1717
Low nuclear	339	425	1029	1793

69 The difference in ETS prices compared to Effective and Widely accepted technologies presented in the Low Carbon Economy Roadmap is due to additional energy efficiency measures, the revised Energy Taxation Directive and changed assumptions for nuclear after Fukushima. The share of nuclear is considerably lower than in decarbonisation scenarios presented in the Low Carbon Economy Roadmap. Current Policy Initiatives and all policy scenarios in this exercise are based on revised assumptions on nuclear (abandonment of the nuclear programme in Italy, change of nuclear policy in Germany, no new nuclear plants in Belgium and upwards revision of costs for nuclear power plants). Moreover, electricity demand is lower due to stringent energy efficiency measures. In addition, assumptions on the potential of electricity in transport were revised, following more closely the scenarios developed in the White Paper on Transport leading to lower utilisation rate of nuclear power plants than in the Low Carbon Economy Roadmap Scenarios. Electric vehicles flatten electricity demand and thus incentivise baseload power generation.

70 A dedicated infrastructure modelling was performed with the PRIMES model and the main results are presented in Annex 1.

The model assumes that grid investments, that are prerequisites to the decarbonisation scenarios in this analysis, are undertaken and that costs are fully recovered in electricity prices. Reality might differ in the sense that the current regulatory regime might be more short to medium term cost minimisation oriented and might not provide sufficient incentives for long-term and innovative investments. There might also be less perfect foresight and lower coordination of investments in generation, transmission and distribution as the model assumes.

Impacts on internal market and competition

Electricity markets might change substantially with an increasing share of generation with close to zero marginal costs. A competitive market would in this situation lead to almost zero prices which would be insufficient to pay for upfront capital investments[71]. A different market design might be needed. While a specific regime for RES (e.g. feed-in tariffs) may be justified in certain situations (e.g. for new RES which are not yet competitive), every effort is needed to ensure that RES is integrated into the energy market, through support, regulatory and infrastructure policies. This is even more the case when RES becomes a significant share of overall energy production (especially in the high RES scenario).

Innovation and R&D

A goal of the Europe 2020 strategy[72] (underpinned by the Communication on the Innovation Union[73]) is to increase innovation in Europe and focus R&D and innovation policies on tackling major societal challenges such as climate change. The EU27 is already a world leader in some segments of low-carbon and energy efficient technologies (nuclear power plants, wind turbines, some energy efficient appliances, etc). All policy scenarios involve significant improvement in efficiency and cost parameters of new technologies as compared to the Reference scenario due to more economies of scale and faster learning rates. The deployment of CCS and some RES in the decarbonisation scenarios, for instance, implies a rate of capacity growth and innovation that is at least as great as that seen for energy technologies in the 20th century[74]. As a consequence all policy options are expected to further boost research and innovation, thereby also improving competitiveness. However, the magnitude of innovation between different policy options might differ. Moreover, impacts expected on innovations can hardly be grasped by current models.

Impacts on third countries

Impacts on third countries, mainly oil and gas importing countries would be significant. Imports in decarbonisation scenarios decrease sharply (besides gas imports in the Low nuclear scenario). In addition, global decarbonisation efforts lead to lower fossil fuel prices. So, under these particular circumstances the export revenues from European customers are 31 to 43% lower in 2050 than in 2005. In the mid-term, in 2030 all decarbonisation scenarios have a higher fuel bill compared to 2005 by at least 35%, but to much lower levels than the

71 The modelling does not show this situation arising because the model assumes full cost recovery of capital investments in all scenarios

72 Europe 2020 COM(2010) 2020

73 EU 2020 Flagship Initiative Innovation Union SEC(2010) 1161

74 The fastest previous scale-up was for electricity generation from nuclear power, which expanded at a rate of approximately 25-30% per year between 1960 and 1980 globally. The decarbonisation scenarios almost all envisage a major roll-out of CCS starting after 2030 and reaching average rates of up to 36% per year in 2030-2040 (20% pa in 2030-2050); similarly but closer to now, certain RES technologies could be soaring, especially from 2010 to 2030 at average annual rates of up to 20% and 15% per year for off-shore wind and solar electricity, respectively.

Reference and Current Policy Initiative scenarios[75]. (See also section on Energy system costs).

There is no major impact on electricity trade, which remains marginal with third countries. The increased global use of biomass for energy purposes might have impacts on food prices and input costs of other biomass-using industries.

Impacts on prices for biomass and land prices

Bioenergy is expected to be an important part of any low-carbon energy strategy. This might have impacts on prices for biomass from agriculture and forest-based industries either directly through increased demand for energy use, or through increased demand for land and thus higher land prices. As most of the biomass used for energy has competing uses (food and feed, renewable raw materials), food prices and input costs of other biomass-using industries are likely to increase.

5.3. Social impacts

Impacts on employment

The social dimension of decarbonisation is crucial as transition to a low carbon economy will require an in depth change in several sectors, affecting companies, employment and working conditions. Education and training need to be addressed at an early stage in order to avoid unemployment in some sectors and labour shortages in others. More knowledge should be gathered about the social implications of deep and long-term decarbonisation as no studies are available yet. Consultations, also in the context of the social dialogue, could improve the follow-up work on the decarbonisation roadmaps[76], including decarbonisation of the energy sector.

Employment effects of decarbonisation policies up to 2020 are generally ambiguous and difficult to assess. A direct positive effect of relative growth in the "green" technology sector is that some subsectors like energy efficiency in buildings are usually assumed to have a relatively high labour intensity. Indirect positive effects for employment may include increased innovation resulting from stricter environmental policy, increased export potential for green technologies, as well as less fossil fuel imports. Negative effects may include transition costs, such as inflexibilities in the labour market to respond to changes in skill demand. There is uncertainty as to whether positive or negative effects would dominate.

However, most studies that evaluate the net employment effects of the EU's 20-20-20 targets record impacts of typically ±1%[77]. A recent extensive macroeconomic study suggests that net employment effects for meeting the EU's targets for 2020 will be small and positive, leading to an average increase in employment demand of up to 0.3%[78]. The two scenarios with the

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75 No further analysis has been done as regards the impact of increased revenues of oil and gas exporting countries on imports from the EU.

76 The social dimension might be better tackled in a decarbonisation roadmap treating all the interdependencies among sectors such as energy, transport, industry and agriculture than in a sectoral roadmap dealing with energy only.

77 See literature review section in the report "Studies on Sustainability Issues- Green Jobs; Trade and Labour" (2011) commissioned by the European Commission, DG Employment.

78 "Studies on Sustainability Issues- Green Jobs; Trade and Labour" (2011) commissioned by the European Commission. The leading objective has been to analyse the employment consequences of the implementation of policies to achieve the key EU environmental targets of a 20% cut in emissions of GHG by 2020 compared to 1990 levels (increasing to 30% if other countries make similar

most ambitious targets (30% GHG emission reductions by 2020, achieving the 20% energy efficiency target) have the highest net effects on employment. Similarly, a 2009 study[79] finds modestly positive net employment effects of up to 0.1% for supporting policies to meet the 2020 RES targets. An assessment of net employment effects of the European decarbonisation objectives towards 2050 was performed in the European Climate Foundation's 2050 Roadmap[80]. It expects net employment to initially be marginally negative and turn positive at a later stage: employment in the decarbonisation scenario is 0.06% below the baseline by 2020 and 1.5% higher than the baseline in 2050. An estimate of net employment effects until 2030 and some quantitative examples of job creation in certain sectors are provided in the IA report on Low Carbon Economy Roadmap[81].The net impact on jobs can be an increase by 0.7% compared to the Reference scenario, corresponding to 1.5 million jobs by 2020.

The overall effects of the increased investment in green technologies on the labour market are thus expected to be fairly modest relative to the effects of other developments such as globalisation, technical progress and demographic change. On a sectoral level, a small increase in jobs in the engineering and construction sectors and a decrease in the energy supplying sectors might arise. The effects on the energy-intensive sectors are ambiguous. Higher energy prices may lead to losses in competitiveness on the one hand while there would also be increased demand for goods from the sector (such as steel and concrete) on the other. However, by focussing on sectoral gains and losses, potentially significant impacts at a more micro level may not be captured in these studies. Also, regional differences may be significant.

As the whole analysis was done in a global climate effort context, there are no job losses due to carbon leakage. However the decision by companies to relocate production away from the EU may be related to other factors such as access to markets or raw materials or secure access to energy sources with long-term price guarantees.

Quality of jobs

The more investments are made in new technologies – many of which are likely to be energy saving or related to new forms of energy generation – the more demand there will be for people in higher skilled jobs (especially professional and associate professional ones). In this way, the greening of the economy can stimulate the demand for highly skilled (and high waged) workers, although the extent to which this will occur even under the most optimistic of scenarios is relatively modest when compared to the business as usual scenario.

Affordability

Affordability of energy services as regards costs for fuel and electricity as well as for equipment, appliances, insulation and transport services is one of the essential elements of the analysis. The sector most concerned is households. All decarbonisation scenarios show significant fuel savings compared to the Reference and CPI scenarios but also higher costs for energy appliances and insulation.

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commitments), a 20% increase in the share of renewable energy, and the objective of a 20% cut in energy consumption (the 20-20-20 targets).

79 "EmployRES: The impact of renewable energy policy on economic growth and employment in the European Union" (2009), commissioned by the European Commission, DG Transport and Energy

80 "Roadmap 2050: a practical guide to a prosperous, low-carbon Europe; Volume 1 – Technical and Economic Analysis" (European Climate Foundation, 2009)

81 SEC(2011) 288 final page 44 and 90-91

Energy related expenditures of households for heating, cooling, lighting, cooking, appliances i.e. excluding transport services, almost double from around 2000 EUR'08 today to 3800-3900 EUR'08 in 2050 in the Reference and CPI scenarios reflecting rising fuel and electricity prices and increasing direct household investments in energy efficiency. Expenditures per household amount to around 4500 EUR'08 in most decarbonisation scenarios in 2050, with expenditure per household reaching some 4800 €(08) and almost 4900 €(08) in the Energy Efficiency and High RES scenarios respectively. It is important to note that per capita income in 2050 will also almost double from today's level, but also that households will be composed of fewer members reflecting aging and changing lifestyles. Energy costs for stationary uses per household exceed the Reference/CPI case level by 16-17% in 2050 in most decarbonisation scenarios. They are 25-27% higher in the Energy Efficiency and High RES scenarios, as these scenarios are particularly investment intensive.
However, energy expenditures including expenses for transport services as a percentage of household expenditure show a different picture. They rise over time in all scenarios from 10% in 2005 to around 16% in 2030, stabilising thereafter to around 15-16% by 2050. Among the decarbonisation scenarios, the costs of the Delayed CCS and the Diversified Supply Technology scenarios, similar to the Reference and CPI scenarios, are at the lower end of this range, whereas the High RES and Energy efficiency scenarios show 2050 costs at the upper end. To the extent that vulnerable consumers would incur similar expenditure increases, in particular the necessary upfront investment to realise later savings may pose an affordability challenge for them.

Security of supply

Import dependency, one of the indicators of security of supply, does not change substantially in 2030 in decarbonisation scenarios compared to the Reference scenario and Current Policy Initiatives scenario due to declining gross inland consumption and imports. There is however a substantial decrease in 2050, driven by increased use of domestic resources, mainly renewables. Import dependency is only 35% in the High RES scenario[82] (compared to 58% in the Reference and CPI scenarios) and 39-40% in the other decarbonisation scenarios besides the Low nuclear scenario (45% due to significant use of fossil fuels with CCS). Decarbonisation will significantly reduce fossil fuel security risks.

Large scale electrification combined with more decentralised power generation from variable sources brings other challenges to high quality energy service at any time. However, there are no standardised indicators for the time being. Moreover, adequate stability of the grid is a precondition for modelling, which is why differences in indicators on the stability of the grid are rather small across scenarios[83].

Safety and public acceptance

Safety concerns might be raised against some power generation technologies as well as against infrastructure and exploration of energy fuels. The public in general perceives technological risks as more important than expert judgement would suggest. Across Europe, public acceptance of different generation technologies and infrastructures differs, but none of them is 100% accepted by local communities where they are (going to be) located. A better and more targeted communication with the concerned public and stakeholders might be needed in the future to assure the EU's energy needs.

Table 10: Selected results of scenario analysis

82 High RES scenario relies mainly on domestic sources of renewable energy.
83 Please see more specialised indicators in Annex 1, part B, section 2.5.

			Current trends		Decarbonisation scenarios				
		2005	*Reference scenario*	*Current Policy Initiatives*	*High Energy Efficiency*	*Diversified Supply Techno-logies*	*High Renewable s*	*Delayed CCS*	*Low nuclear*
Primary energy demand reduction (in % from 2005)[84]	2030		-5.3	-10.8	-20.5	-16	-17.3	-16.1	-18.5
	2050		-3.5	-11.6	-40.6	-33.3	-37.9	-32.2	-37.7
Electrification	2030	20.2	25.1	24.5	25.2	26.0	25.4	26.0	25.7
	2050	-	29.1	29.4	37.3	38.7	36.1	38.7	38.5
Fuels (in %)									
Renewables in gross final energy	2030	8,6	23.9	24.7	27.6	27.7	31.2	28	28.8
	2050	-	25.5	29	57.3	54.6	75.2	55.7	57.5
CCS in power generation	2030	0	2.9	0.8	0.7	0.8	0.6	0.7	2.1
	2050	-	17.8	7.6	20.5	24.2	6.9	19	31.9
Nuclear energy in primary energy	2030	14,1	14.3	12.1	11.1	13.9	9.7	13.2	8.4
	2050	-	16.7	13.5	13.5	15.3	3.8	17.5	2.6
Fuels in electricity generation (in%)									
RES	2030	14.3	40.5	43.7	52.9	51.2	59.8	51.7	54.6
	2050	-	40.3	48.8	64.2	59.1	86.4	60.7	64.8
CCS	2030	0.0	2.9	0.8	0.7	0.8	0.6	0.7	2.1
	2050	-	17.8	7.6	20.5	24.2	6.9	19.0	31.9
NUC	2030	30.5	24.5	20.7	18.6	21.2	15.8	21.5	13.4
	2050	-	26.4	20.6	14.2	16.1	3.6	19.2	2.5
Average electricity prices (in EUR'08 per MWh, after tax)[85]	2030	109,3	154,8	156,0	154,4	159,6	164,4	160,4	168,2
	2050	-	151,1	156,9	146,7	146,2	198,9	151,9	157,2
Annual energy system costs related to GDP (in % 2011 – 2050)		-	14.37	14.58	14.56	14.11	14.42	14.06	14.21
Import dependency (in %)	2030	52,5	56.4	57.5	56.1	55.2	55.3	54.9	57.5
	2050	-	57.6	58.0	39.7	39.7	35.1	38.8	45.1

Source: PRIMES modelling

Table 11: Summary of impacts

	1 Reference scenario	1bis Current Policy Initiatives	2 High Energy Efficiency	3 Diversified supply technologies	4 High RES	5 Delayed CCS	6 Low nuclear
Environmental impacts							
Energy consumption/Energy intensity			+ + +	+	+ +	+	+ +
RES share		+	+ +	+ +	+ + +	+ +	+ +
Energy related CO2 emissions		=	+ + +	+ + +	+ + +	+ + +	+ + +
Economic impacts							
Economic growth		=	=	=	=	=	=
Competitiveness		=	+	+	+	+	+

84 Results for primary energy consumption should not be confused with the energy saving targets for 2020 which is calculated against the projected consumption for 2020. Relating this savings objective to energy consumption in 2005, similar to the calculations in the scenarios, would be equivalent to a saving target of 14% in 2020.

85 The price projections ensure full recovery of costs associated with electricity supply in order to depict scenarios in which the investment in production, storage, grids, taxes, etc are fully covered by revenues from selling electricity. In that sense they are not forecasts of future electricity prices, as systems may evolve, in which, contrary to the overall practice today, such investments are partly remunerated by other schemes.

Energy security (import dependency and imports from third countries)		=	+ +	+ +	+ + +	+ +	+
Social impacts							
Employment		=	+ +	+	+ +	+	+
Quality of jobs		=	+ +	+ +	+ +	+ +	+ +
Affordability		=	-	=	-	=	=

Legend:
= equivalent to Reference scenario
+ to +++ improvement compared to Reference scenario
- to - - - worsening compared to Reference scenario

5.5 Sensitivity analysis

It is clear that the robustness of modelling results is affected by the assumptions underlying the modelling scenarios. As outlined in section 2.4, sensitivity analysis has been carried out for the Reference scenario by varying two key parameters – GDP and energy import prices. The conclusions on GDP analysis are quite robust showing that key policy indicators do not vary significantly with GDP given feedback mechanisms and the architecture of EU energy and climate policies (ETS). Following this pattern, a similar outcome might be expected for policy scenarios even though it has not been demonstrated by current analysis. This holds also for variations in energy import prices, although the results are somewhat less stable regarding certain indicators, such as import dependency. Impacts of additional variations in import price assumptions in decarbonisation scenarios (very high oil price and oil shock scenarios) were analysed in the Low Carbon Economy Roadmap.

Constant climate conditions were assumed over time. This simplification may be justified given that all decarbonisation scenarios assume that the climate targets are met. However, even when temperature changes are limited to 2 degree Celsius, some climate impacts will occur.[86] In addition, changes in temperature will lead to changes in energy demand patterns for heating and cooling. It can hence be expected that decarbonisation leads to further positive economic impacts with regard to energy security and competitiveness by avoiding parts of the expected damage and adaptation costs in the energy system due to climate change impacts.

Other assumptions are embedded in the design of policy scenarios. Policy scenarios assume different costs and timing of technology (delay of CCS, faster penetration of RES) and can therefore be interpreted as sensitivity analysis on R&D and learning curves for main technologies. Changes in other sectors such as a higher uptake of electricity in transport, were implicitly studied in this report by assuming that the main thrust of the policies included in the

86 A literature review on climate change impacts in the European energy supply sector as part of the European Commission contract "Climate proofing EU policies" has identified the following main impacts:
- Cooling water constraints for thermal power generation (especially during heat waves), with nuclear appearing to be the most vulnerable technology
- Damage to offshore or coastal production facilities due to sea level rise and storm surges
- Damage to transmission and distribution lines due to storm events, flooding
- Unpredictable hydropower potential
- Affected yield in renewable energy sector (hydropower in Southern Europe, possibly biofuels due to vector diseases and forest fires)
- Melting permafrost affecting energy production and distribution in cold climates
- Damages and output constraints in wind energy due to storms and increased average wind speed

2011 White Paper on Transport is also pursued in these decarbonisation scenarios. No additional transport related policies were examined.

6. SECTION 6: COMPARING THE OPTIONS

This section provides an assessment of how the policy options will contribute to the realisation of the policy objectives, as set in Section 3, in light of the following evaluation criteria:

– **effectiveness** – the extent to which options achieve the objectives of EU energy policy[87];
– **efficiency** – the extent to which objectives can be achieved at least cost;
– **coherence** – the extent to which policy options are likely to limit trade-offs across the economic, social, and environmental domains.

Effectiveness
As regards effectiveness, the three objectives of energy policy – sustainability, security of supply and competitiveness - were taken into account. All policy scenarios were designed to reach 85% reduction of energy related CO2 emissions in 2050, so all are effective in that sense. It should be noted that some scenarios are highly dependent on success of new technologies that are still under demonstration or only partly proven commercially (CCS, off-shore wind, 3rd generation nuclear etc). For the other two objectives the question of most suitable indicators arises. As regards security of supply, all policy scenarios improve import dependency, the best being the High RES scenario with 35% import dependency in 2050 and the least effective the Low nuclear scenario with 45% in 2050 (as compared to 58% in the Reference scenario). However, in a more electrified world, stability of the grid might be of much higher concern with major challenges ahead that can be met as demonstrated by the modelling of the scenarios. As regards competitiveness, some scenarios show a small decrease in electricity prices as compared to the Reference and CPI scenarios (High Energy Efficiency, Diversified supply technologies) while some others show increases (High RES and to a lesser extent Low nuclear). ETS prices are significantly higher than in the Reference and CPI scenarios with the highest values in Delayed CCS scenario and lowest in High Energy Efficiency scenarios where decarbonisation is triggered also by specialised measures. The model triggers adequate investments which are driven by specific policies or carbon prices and investment decisions are based on perfect foresight assumption. All decarbonisation scenarios foster innovation and R&D.

Efficiency
In terms of efficiency, the analysis demonstrates that the costs of decarbonisation of the energy system are not substantially higher compared to the Reference scenario and most decarbonisation scenarios even show a lower annual average cost than the CPI scenario. The least costly scenarios are Delayed CCS and Diversified Supply Technologies scenarios with significant penetration of nuclear.

Coherence
All policy scenarios are coherent with other EU long term objectives (on climate, transport, etc). There is no clear winner among policy options scoring the best in all criteria and several trade-offs will need to be taken into account. The role of this analysis is not to select one

[87] It has been considered more useful to check scenarios against objectives of the EU energy policy than against those of the Roadmap that focus on instruments and processes to deliver more certainty to investors.

preferred pathway but rather to identify the pros and cons of different options and identify common elements from all of them.

Table 12: Comparison of policy scenarios to the Reference scenario

	1bis. Current Policy Initiatives	2. High Energy Efficiency	3. Diversified supply technologies	4. High RES	5. Delayed CCS	6. Low nuclear
Effectiveness						
Sustainability	=	+ + +	+ + +	+ + +	+ + +	+ + +
Security of supply	=	+ +	+ +	+ + +	+ +	+
Competitiveness	=	+	+	+	+	+
Efficiency						
Additional annual average total costs relative to Reference scenario in bn EUR'08	37	33	-47	8	-57	-29
Additional annual average total costs as % of GDP	0.21%	0. 19%	-0.26%	0.05%	-0.31%	-0.16%
Coherence						
Trade-offs between economic, social and environmental impacts		Scenario reducing the most energy consumption and significantly improving import dependency but rather costly for households and difficult to implement when it comes to behavioural changes	Scenario with lowest cost from the economic actors' point of view, significant energy efficiency gains and renewables shares but depending on success (technological progress of CCS and some RES as well as public acceptance of nuclear and CCS)	Scenario showing the highest penetration of RES; highest decrease in import dependency and second strongest reduction of energy consumption pushing innovation in new technologies, but rather costly and leading to highest electricity prices	Scenario with lowest costs scoring well on security of supply, RES penetration and competitiveness but the least effective in terms of energy efficiency; rather strong reliance on nuclear being contingent on absence of further public acceptance problems	Scenario scoring well on costs, RES shares and energy efficiency but still with high consumption of fossil fuels and dependency on their imports. Heavily dependent on technological progress and acceptance of CCS

Legend:
= equivalent to Reference scenario
+ to +++ improvement compared to Reference scenario
- to - - - worsening compared to Reference scenario

Conclusions

The Commission services conducted a model-based analysis of decarbonisation scenarios exploring energy consequences of the European Council's objective to reach 80% GHG reductions by 2050 (as compared to 1990), provided that industrialised countries as a group undertake similar efforts. These scenarios explore also the energy security and competitiveness dimension of such energy developments. Businesses as usual projections show only half the GHG emission reductions needed; increased import dependency, in particular for gas; and rising electricity prices and energy costs. Several decarbonisation scenarios highlighting the implications of pursuing each of the four main decarbonisation routes for the energy sector – energy efficiency, renewables, nuclear and CCS - were examined by modelling a high and low end for each of them. The model relies on a series of input assumptions and internal mechanisms to provide the outputs.

The most relevant assumptions and mechanisms of the model

- All scenarios were conducted under the hypothesis that the whole world is acting on climate change which leads to lower demand for fossil fuel prices and subsequently lower prices.
- The model assumes perfect foresight regarding policy thrust, energy prices and technology developments which assures a very low level of uncertainty for investors, enabling them to make particular cost-effective investment choices without stranded investments. There is also no problem with uncertainty on whether all the infrastructure and other interrelated investment needed to make a particular investment work will be in place in time.
- Regulatory framework in model allows for investments to be built and costs fully recovered.
- The model assumes a "representative" or average household or consumer while in reality there is a more diversified picture of investors and consumers.
- The model assumes continuous improvements of technologies.

The model-based analysis has shown that decarbonisation of the energy sector is feasible; that it can be achieved through various combinations of energy efficiency, renewables, nuclear and CCS contributions; and that the costs are affordable. The aim of the analysis was not to pick preferred options, a choice that would be surrounded with great uncertainty, but to show some prototype of pathways to decarbonise the energy system while improving energy security and competitiveness and identify common features from scenario analysis.

Common elements to scenario analysis

- There is a need for an integrated approach, e.g. decarbonisation of heating and transport relies heavily on the availability of decarbonised electricity supply, which in turn depends on very low carbon investments in generation capacity as well as significant grid expansions and smartening.
- Electricity (given its high efficiency and emission free nature at use) makes major inroads in decarbonisation scenarios reaching a 36-39% share in 2050 (almost doubling from the current level and becoming the most important final energy source). Decarbonisation in 2050 will require an almost carbon free electricity sector in the EU, and around 60% CO2 reductions by 2030.
- Significant energy efficiency improvements happen in all decarbonisation scenarios. One unit of GDP in 2050 requires around 70% less energy input compared with 2005. The average annual improvement in energy intensity amounts to around 2.5% pa.
- The share of renewables rises substantially in all scenarios**,** achieving at least 55% in gross final energy consumption in 2050, up 45 percentage points from the current level (a high RES case explores the consequences of raising this share to 75%).
- The increased use of renewable energy as well as energy efficiency improvements require modern, reliable and smart infrastructure including electrical storage.
- Nuclear has a significant role in decarbonisation in Member States where it is accepted in all scenarios (besides Low nuclear and High RES), with the highest penetration in case of CCS delay.
- CCS contributes significantly towards decarbonisation in most scenarios, with the highest penetration in case of problems with nuclear investment and deployment. Developing CCS can be also seen as an insurance against energy efficiency, RES and nuclear (in some Member States) delivering less or not that quickly.
- All scenarios show a transition from high fuel/operational expenditures to high capital expenditure.
- Substantial changes in the period up to 2030 will be crucial for a cost-efficient long term transition to a decarbonised world[88]. Economic costs are manageable if action starts early so that the

[88] Scenarios for the Low Carbon Economy Roadmap of March 2011 show the additional costs of delayed action.

restructuring of the energy system goes in parallel with investment cycles thereby avoiding stranded investment as well as costly lock-ins of medium carbon intensive technology.

- The costs of such deep decarbonisation are low in all scenarios given lower fuel procurement costs with cost savings shown mainly in scenarios relying on all four main decarbonisation options.
- Costs are unequally distributed across sectors, with households shouldering the greatest cost increase due to higher costs of direct energy efficiency expenditures in appliances, vehicles and insulation.
- The external EU energy bill for importing oil, gas and coal will be substantially lower under decarbonisation due to a substantial reduction in import quantities and prices dependent on global climate action lowering world fossil fuel demand substantially.

Some policy relevant conclusions can be drawn based both on the results of the scenario analysis as well as on a comparison of the hypothetical situation of ideal market and technological conditions needed for modelling purposes and what is found in the much more complex reality.

Implications for future policy making

- Successful decarbonisation while preserving competitiveness of the EU economy is possible. Without global climate action, carbon leakage might be an issue and appropriate instruments could be needed to preserve the competitiveness of energy intensive industries.
- Predictability and stability of policy and regulatory framework creates a favourable environment for low carbon investments. While the regulatory framework to 2020 is mainly given, discussions about policies for 2020-2030 should start now leading to firm decisions that provide certainty for long-term low-carbon investments. Uncertainty can lead to a sub-optimal situation where only investment with low initial capital costs is realised.
- A well functioning internal market is necessary to encourage investment where it is most cost-effective. However, the process of decarbonisation brings new challenges in the context, for example, of electricity price determination in power exchanges: deep decarbonisation increases substantially the bids based on zero marginal costs leading in many instances to prices rather close to zero, not allowing cost recovery in power generation. Similarly, the necessary expansion and innovation of grids for decarbonisation may be hampered if regulated transmission and distribution focuses on cost minimisation alone. Building of adequate infrastructure needs to be assured and supported either by adequate regulation and/or public funding (e.g. financed by auctioning revenues).
- Energy efficiency tends to show better results in a model than in reality. Energy efficiency improvements are often hampered by split incentives, cash problems of some group of customers; imperfect knowledge and foresight leading to lock-in of some outdated technologies, etc. There is thus a strong need for targeted support policies and public funding supporting more energy efficient consumer choices.
- Strong support should be given to R&D in order to bring costs of low-carbon technologies down and to minimize potential negative environmental and social side-effects.
- Due attention should be given to public acceptance of all low carbon technologies and infrastructure as well willingness of consumers to undertake implied changes and bear higher costs. This will require the engagement of both the public and private sectors early in the process.
- Social policies might need to be considered early in the process given that households shoulder large parts of the costs. While these costs might be affordable by an average household, vulnerable consumers might need specific support to cope with increased expenditures. In addition, transition to a decarbonised economy may involve shifts to more highly skilled jobs, with a possibly difficult adaptation period.
- Flexibility. The future is uncertain and nobody can predict it. That is why preserving flexibility is important for a cost efficient approach, but certain decisions are needed already at this stage in order to start the process that needs innovation and investment, for which investors require a reasonable degree of certainty from reduced policy and regulatory risk.

- External dimension, in particular relations with energy suppliers, should be dealt with pro-actively and at an early stage given the implications of global decarbonisation on fossil fuel export revenues and the necessary production and energy transport investments during the transition phase to decarbonisation; new areas for co-operation could include renewable energy supplies and technology development.

7. Monitoring and Evaluation

The Roadmap is not a one-off exercise and will be regularly updated taking into account the most recent developments. In addition, the Commission will constantly monitor a set of core indicators which are already available and are being currently used. Other indicators might be added at a later stage.

Table 12: Key indicators and their relevance

KEY INDICATORS	2009	RELEVANCE
Share of RES in gross final energy consumption	10.3% (2008)	Increase in RES use in the economy
Share of renewable energy in transport	3.5% (2008)	Increase in RES use in the transport
Energy intensity	165.48 (toe/M€ '00)	Increase in energy efficiency
Gross inland consumption (by fuel)	1703 Mtoe http://ec.europa.eu/energy/publications/statistics/doc/2011-2009-country-factsheets.pdf	Changes in the overall demand and composition of energy mix over time; existing indicative energy saving objective for 2020
Energy per capita	3403 kgoe/cap	Evolution of energy consumption relative to population growth
Final energy consumption (by fuel and by sector)	1114 Mtoe http://ec.europa.eu/energy/publications/statistics/doc/2011-2009-country-factsheets.pdf	Decrease in absolute energy consumption and effectiveness of energy efficiency policies as well as sectoral developments
Electricity generation	3210 TWh	Electrification of the economy
Energy related CO2 emissions	4055 MT CO2	Trends in the emissions from the energy sector; lion's share in total GHG emissions
Import dependency for all fuels	54%	Vulnerability to imports from third countries
Electricity prices	http://ec.europa.eu/energy/observatory/electricity/electricity_en.htm http://ec.europa.eu/energy/observatory/reports/EnergyDailyPricesReport-EUROPA.pdf	Competitiveness of European industry and affordability for households
Diesel and petrol prices in different MS	http://ec.europa.eu/energy/observatory/oil/bulletin_en.htm	Evolution in prices of transport fuels and their convergence across the EU 27
Total GHG emissions compared to 1990	-17.4% http://ec.europa.eu/clima/policies/g-gas/docs/com_2011_624_en.pdf	Meeting climate targets

8. Annexes

Annex 1 Scenarios - assumptions and results

Annex 2 Report on Stakeholders scenarios

Annex 1 Scenarios – assumptions and results

This document describes in detail the assumptions and results of the Reference scenario 2050 and its sensitivities, Current Policy Initiatives scenario and decarbonisation scenarios developed for the purposes of the Energy Roadmap 2050.

The Commission contracted the National Technical University of Athens to model scenarios underpinning the Impact Assessment analysis. Similar to previous modelling exercises with the PRIMES model, the Commission discloses a lot of details about the PRIMES modelling system, modelling assumptions and modelling results. In this tradition, the Commission services, based on the modelling results and analysis on specific topics from NTUA, have drafted the following comprehensive overview of the macroeconomic, world energy price, policy, technology and other assumptions as well as the detailed results of the current trend scenarios including sensitivities (Part A) and the various decarbonisation scenarios (Part B). This is complemented with the attachments to this document giving further details.

The PRIMES model was peer-reviewed by a group of recognised modelling experts in September 2011 with the conclusion that the model is suitable for the purpose of complex energy system analysis.

Reference scenario is based on the scenarios up to 2030 published in the report "Energy Trends to 2030: update 2009", but extends the projection period to 2050. It includes current trends on population and economic development and takes into account the highly volatile energy import price environment. Economic decisions are driven by market forces and technology progress in the framework of concrete national and EU policies and measures implemented until March 2010. These assumptions together with the current statistical situation derived from the Eurostat energy balances represent the starting point for projections which are presented from 2010 onwards in 5 year steps until 2050. The 2020 targets on RES and GHG will be achieved, but there is no assumption on targets for later years. Sensitivities on higher/lower economic growth and higher/lower energy import prices were undertaken in order to assess the robustness of policy relevant indicators with respect to these framework conditions for EU energy policy.

The overall policy context has developed since the Reference scenario was established in 2010. Therefore an additional trend scenario has been modelled including policies that are being prepared with a view to the 2020 Energy Strategy. The **Current Policy Initiatives scenario** includes the same macroeconomic and demographic assumptions as the Reference scenario, slightly updated energy import prices (only for 2010 with repercussions on 2015), revised cost-assumptions for nuclear following post Fukushima reactions and policies either adopted after March 2010 or being currently proposed by the Commission.

In addition to their role as a trend projection, the Reference and the Current Policy Initiatives scenarios are benchmarks for energy scenarios achieving the European Council's objective to reduce GHG by 80-95% below the 1990 level as part of industrialised countries as a group undertaking such a reduction effort. Comparisons of other scenarios with the Reference scenario concern questions related to the additional policies with respect to those already implemented in the Member States. Distinct from this, comparisons of the Current Policy Initiatives scenario with decarbonisation scenarios address further policies that might be envisaged in addition to those being proposed in the context of the 2020 Energy Strategy. Such comparisons on the basis of the Current Policy Initiatives scenario deal with new policies that might be debated under a 2030 horizon, which is an important milestone year on the decarbonisation pathways to 2050.

Decarbonisation scenarios in the Energy Roadmap 2050 have been designed to provide more detail on the analysis of the energy sector that was presented in the Low Carbon Economy Roadmap. Scenarios showing different energy related decarbonisation pathways reach the 85% domestic energy related CO_2 emission reductions by 2050 as compared to 1990 which is consistent with the required contribution of developed countries as a group to limit global climate change to a temperature increase of 2ºC compared to pre-industrial levels. All decarbonisation scenarios developed for the Low carbon Economy Roadmap show around 85% reductions of energy related CO_2 emissions.

The scenarios modelled for the 2050 Energy Roadmap investigate in great depth the main strategic directions (energy efficiency, RES, CCS and nuclear) towards a decarbonised European energy system. In doing so, they reflect for each of these directions or main ways of decarbonisation a low and a high end option. This underlines the fact that there are many different pathways for reaching the same level of decarbonisation in the EU.

All numbers included in this report, except otherwise stated, refer to European Union of 27 Member States.

PART A: REFERENCE SCENARIO AND ITS SENSITIVITIES AND CURRENT POLICY INITIATIVES SCENARIO

1. ASSUMPTIONS

1.1 Macroeconomic and demographic assumptions

The population projections draw on the EUROPOP2008 convergence scenario (EUROpean POPulation Projections, base year 2008) from Eurostat, which is also the basis for the 2009 Ageing Report (European Economy, April 2009)[89]. The key drivers for demographic change are: higher life expectancy, low fertility and inward migration.

The macro-economic projections reflect the recent economic downturn, followed by sustained economic growth resuming after 2010. The medium and long term growth projections follow the “baseline” scenario of the 2009 Ageing Report (European Economy, April 2009), which derives GDP growth per country on the basis of variables such as population, participation rates in the labour market and labour productivity.[90] Based on the Ageing Report the Commission services developed a common Reference scenario, the macroeconomic part of which is referred to below. Further details relating notably to the sectoral value added can be found in the report "EU Energy Trends to 2030".[91] The same macroeconomic assumptions were already used for the "Roadmap for moving to a competitive low-carbon economy in 2050" of March 2011.[92]

The Reference scenario assumes that the recent economic crisis has long lasting effects, leading to a permanent loss in GDP. The recovery from the crisis is not expected to be so vigorous that the GDP losses during the crisis are fully compensated. In this scenario, growth prospects for 2011 and 2012 are subdued. However, economic recovery enables higher productivity gains, leading to somewhat faster growth from 2013 to 2015. After 2015, GDP growth rates mirror those of the 2009 Ageing Report. Hence the pattern of the Reference scenario is consistent with the intermediate scenario 2 “sluggish recovery” presented in the Europe 2020 strategy[93].

The average growth rate for EU-27 is only 1.2% per year for 2000-2010, while the projected rate for 2010-2020 is recovering to 2.2%, similar to the historical average growth rate between 1990 and 2000. GDP increases in line with the Ageing Report developments, depicting declining growth rates over time as well as great variation among Member States. Recovering from the crisis (reflected by only 0.6% pa GDP growth in 2005-2010), EU-27

[89] European Commission, DG Economic and Financial Affairs: 2009 Ageing Report: Economic and budgetary projections for the EU-27 Member States (2008-2060). EUROPEAN ECONOMY 2|2009, http://ec.europa.eu/economy_finance/publications/publication14992_en.pdf. The “baseline” scenario of this report has been established by the DG Economic and Financial Affairs, the Economic Policy Committee, with the support of Member States experts, and has been endorsed by the ECOFIN Council.

[90] European Commission, DG Economic and Financial Affairs: 2009 Ageing Report: Economic and budgetary projections for the EU-27 Member States (2008-2060). EUROPEAN ECONOMY 2|2009, http://ec.europa.eu/economy_finance/publications/publication14992_en.pdf

[91] EU energy trends to 2030, Directorate General for Energy in collaboration with Climate Action DG and Transport DG, 2010

[92] COM(2011)112, 8 March 2011

[93] Communication from the Commission: Europe 2020. A strategy for smart, sustainable and inclusive growth. COM(2010)2020, Brussels, 3.3.2010.

GDP is expected to rise 1.7% per annum (pa) from 2010 to 2050, and more specifically by 2.0% up to 2030 and only 1.5% pa after 2030. EU-12 growth is considerably higher in 2010-2030 (2.7% pa) but significantly smaller post 2030 due to shrinking and ageing population (0.9% pa).

The recent economic crisis has added sustainability problems to the public finances. Overall, as an effect of both economic crisis and the ageing of the population, without fiscal consolidation the gross debt-to-GDP ratio for the EU as a whole could reach 100 percent as early as 2014 and 140 percent by 2020[94,95]. The recent economic crisis might therefore limit the public funding available for low carbon investments.

Sensitivities – Higher and Lower GDP cases

Considering the high degree of uncertainty surrounding projections over such a long time horizon, a sensitivity analysis has been carried out with respect to GDP developments. A high and a low case have been analysed. The GEM-E3 model was deployed to simulate higher and lower expansion paths for GDP growth, while all other assumptions, including world fossil fuel prices, have remained the same.

Table 1: EU-27 GDP in real terms in the high and low economic growth variants, compared to the Reference scenario GDP

	2010	2020	2030	2040	2050
Reference (M€05)	11386	14164	16825	19528	22560
High economic growth (M€05)	11386	14488	17889	21596	25953
	0.0%	*2.3%*	*6.3%*	*10.6%*	*15.0%*
Low economic growth (M€05)	11386	13605	15527	17322	19239
	0.0%	*-3.9%*	*-7.7%*	*-11.3%*	*-14.7%*

Table 2: Average annual growth rate for the EU-27

	05-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
Reference	0.58	2.29	2.13	1.82	1.65	1.54	1.47	1.47	1.44
High economic growth	0.58	2.37	2.51	2.22	2.05	1.93	1.87	1.87	1.84
Low economic growth	0.58	1.89	1.70	1.41	1.25	1.13	1.07	1.07	1.04

The two economic growth variants are designed to provide insights into the energy system developments stemming from alternative outcomes on economic drivers of energy consumption. In the high growth variant, GDP per capita is 0.4 percentage points higher than in the Reference case throughout the projection period, whereas it would be 0.4 pp lower in the low growth case. These variants examine the energy consequences of alternative economic developments broken down by economic sector in particular with regard to activities of energy intensive sectors versus less intensive ones.

Higher GDP growth would be driven mainly by enhanced activities of the services sector, with particular high value added growth in market services and trade, as these sectors are not

[94] European Commission, DG Economic and Financial Affairs: Sustainability Report 2009. EUROPEAN ECONOMY 9|2009, http://ec.europa.eu/economy_finance/publications/publication15998_en.pdf.

[95] European Commission, DG Economic and Financial Affairs: Public Finances in EMU 2010. EUROPEAN ECONOMY 4|2010, http://ec.europa.eu/economy_finance/publications/european_economy/2010/pdf/ee-2010-4_en.pdf.

very energy intensive. By comparison, industrial value added would exhibit less additional growth with expansion rates lower than that of GDP Both energy intensive and less energy intensive industrial sectors would however still show healthy additional growth.

In the low economic growth variant, all economic sectors would suffer to a similar extent with value added in most cases being 14-15% lower in 2050 than in the Reference case. One exception would be agriculture where the decrease in output with respect to the Reference case would be smaller.

1.2 Energy import prices

The energy projections are based on a relatively high oil price environment compared with previous projections and are similar to reference projections from other sources[96]. The baseline price assumptions for the EU27 are the result of world energy modelling (using the PROMETHEUS stochastic world energy model) that derives price trajectories for oil, gas and coal under a conventional wisdom view of the development of the world energy system.

International fuel prices are projected to grow over the projection period with oil prices reaching 88$'08/bbl in 2020, 106$'08/bbl in 2030 and 127 $08/barrel in 2050 with 2% inflation (ECB target) this corresponds to some 300 $ in 2050 in nominal terms.

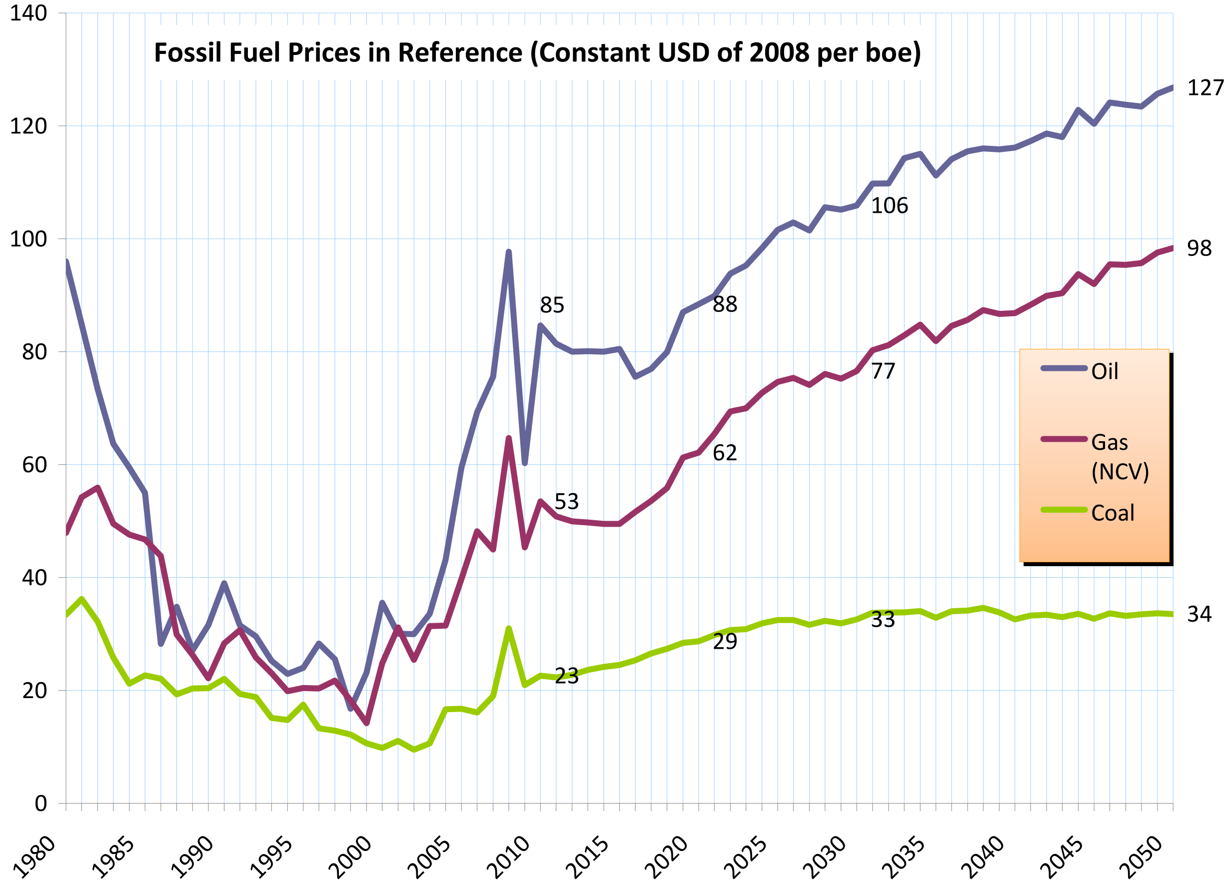
Gas prices follow a trajectory similar to oil prices reaching 62$'08/boe in 2020, 77$'08/boe in 2030 and 98 $(08)/boe in 2050 while coal prices increase during the economic recovery period to reach almost 26$'08/boe in 2020 and stabilize at around 30$'08/boe.[97]

The price development to 2050 is expected to take place in a context of economic recovery and resuming GDP growth without decisive climate action in any world region. Prices were derived with world energy modelling that shows largely parallel developments of oil and gas prices whereas coal prices remain at much lower levels.

[96] This refers to energy projections from the US Energy Information Administration (EIA) and the International Energy Agency (IEA). The EIA International Energy Outlook 2009 assumed 130 $/barrel in 2007 prices for 2030, equivalent to 134 $/barrel in 2008 prices. The IEA World Energy Outlook 2009 assumed 115 $/barrel in 2008 prices for 2030.

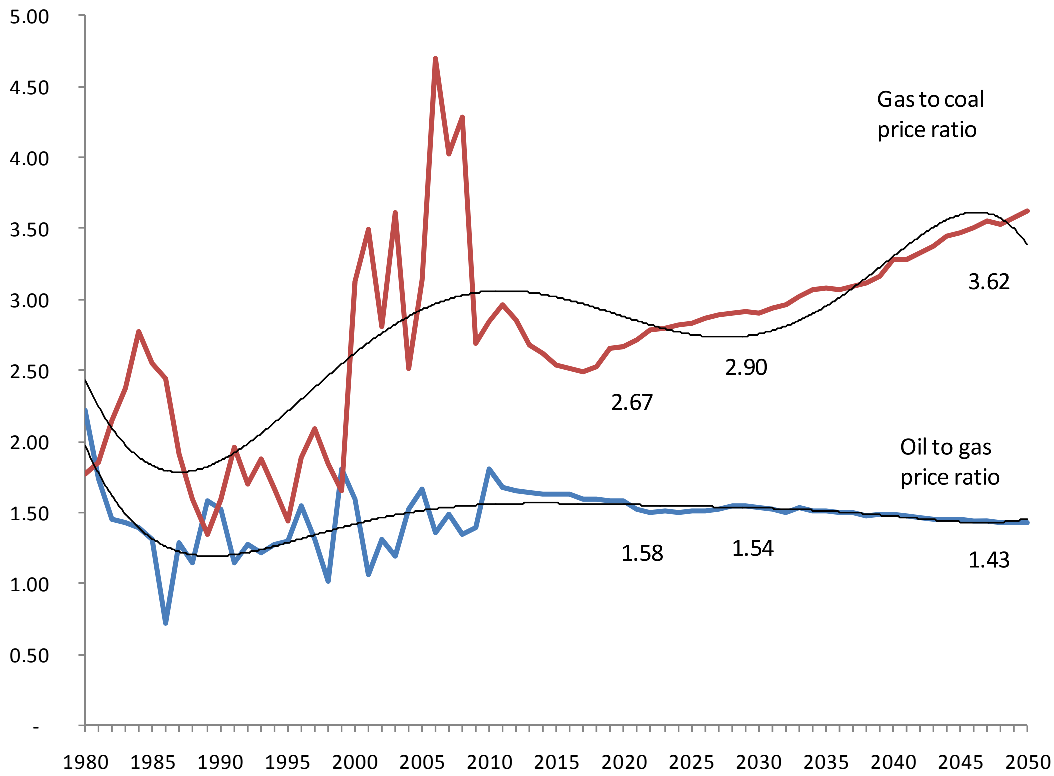
[97] As the model operates in constant euros, for which the exchange rate is assumed to depreciate from the currently high levels of around 1.4 $/€, there will be a somewhat faster increase in energy prices in euros than in dollar.

Figure 1: Reference scenario fossil fuel price assumptions



The evolution of the ratio of gas and coal prices can to a great extent influence the investment choices taken by investors in the power sector. A relatively low gas to coal price ratio up to the year 2000, together with the emergence of the gas turbine combined cycle technology, led to massive investments in gas fired power plants. The investments decreased afterwards due to significant gas price increases. The ratio between gas and oil prices remains stable over time as gas prices continue to follow oil prices. The gas to coal price ratio is projected to rise steadily over time as the coal prices in the world modelling results do not follow oil prices but remain around 30$'08/boe from 2030 onwards. While this ratio will increase over time, investment decisions will also be highly dependent on the expectations about future carbon prices.

Figure 2: Ratios of fossil fuel prices



Sensitivities: Higher and lower energy import prices

Considering the high degree of uncertainty surrounding projections over such a long time horizon, a sensitivity analysis has been carried out with respect to developments in energy imports prices. A high and a low case have been analysed. When undertaking the price sensitivities in 2011, the energy price figures for 2010 were updated from the estimates made in early 2009 for the Baseline/Reference scenario (in the same way as in the Reference case).[98] Global developments as regards shale gas are taken into account in this analysis.

The world energy model PROMETHEUS was deployed to derive the alternative prices trajectories. This stochastic model is particularly well suited given the great uncertainty regarding future world economic developments and the extent of recoverable resources of fossil fuels. Two different world energy price developments have been examined. The high world fossil fuel price development is driven by somewhat higher global GDP growth than under reference developments, especially in China, giving rise to higher energy consumption. Moreover, there are somewhat less optimistic assumptions on reserves regarding unconventional oil, which has the highest marginal costs. This favours stronger market power of key exporting countries and thereby higher prices. On the contrary, the low world energy

98 The price sensitivities presented in this IA complement those made in the Impact Assessment for the Low Carbon Economy Roadmap, which included an oil shock case in 2030 with oil prices suddenly rising to 212 $(08)/barrel, representing a doubling from Reference case in that year. In the following years, the genuine oil shock case depicts some oil demand reaction and a subsequent gradual decline of oil prices towards Reference case levels without reaching those, not even in 2050 (still being 18% higher). On the contrary, an alternative development was also examined, in which the oil prices would stay at the high 212 $/barrel level throughout the rest of the projection period. In the latter case, the 2050 oil price exceeds the Reference case level still by two thirds. (Results can be found in the above mentioned Impact Assessment and are not repeated here).

prices derive from markedly more subdued world economic growth combined with higher fossil fuel reserves and consequently less market power of key export players.

The sensitivities below are more symmetrical around the Reference case, including a High Price case with oil prices exceeding the Reference case level by 28% in 2050 and a Low Price case, in which the oil price in 2050 is 34 % lower than in the Reference case.

The price trajectories for oil, gas and coal shown in table 3 for the high energy price scenario stem from the following developments mirrored in the world modelling analysis:

- There is sustained economic growth in many Asian economies (notably China) following their reaction to the recent crisis, which has been to support domestic market expansion as a counterweight. The result has been that economic growth in the large Asian economies like China and India has barely been affected by the world economic slowdown. Since these are large consumers of coal the effect of this economic activity revision is particularly pronounced on short to medium term coal prices.
- There appears to be pronounced delays in oil productive capacity expansion with many plans being constantly revised. In addition, the recent accident in the Gulf of Mexico has resulted in a moratorium on deep water development in that area and is likely to result in delays in other parts of the world as well, in response to increased environmental concerns.
- There is increased concern that oil reserves and prospects for undiscovered resources are overstated. This may be particularly the case in OPEC countries where resource endowment is used as a criterion for production quota allocations.
- In view of the oligopolistic nature of world oil markets the tighter supply conditions usually translate into disproportionate increases in resource rents. Likewise such conditions imply greater vulnerability to short term supply disruptions leading to price spikes and resulting in higher average prices.
- The higher oil prices result in substitution of oil for gas in markets where the two fuels compete. The reduction in oil discoveries also implies a reduction in future reserves of associated gas. On the other hand gas price increases are moderated by an increasing share of unconventional gas from shales, as technology improves and the interest in its potential spreads beyond North America.

The low energy price scenario has been based on the following hypothetical background:

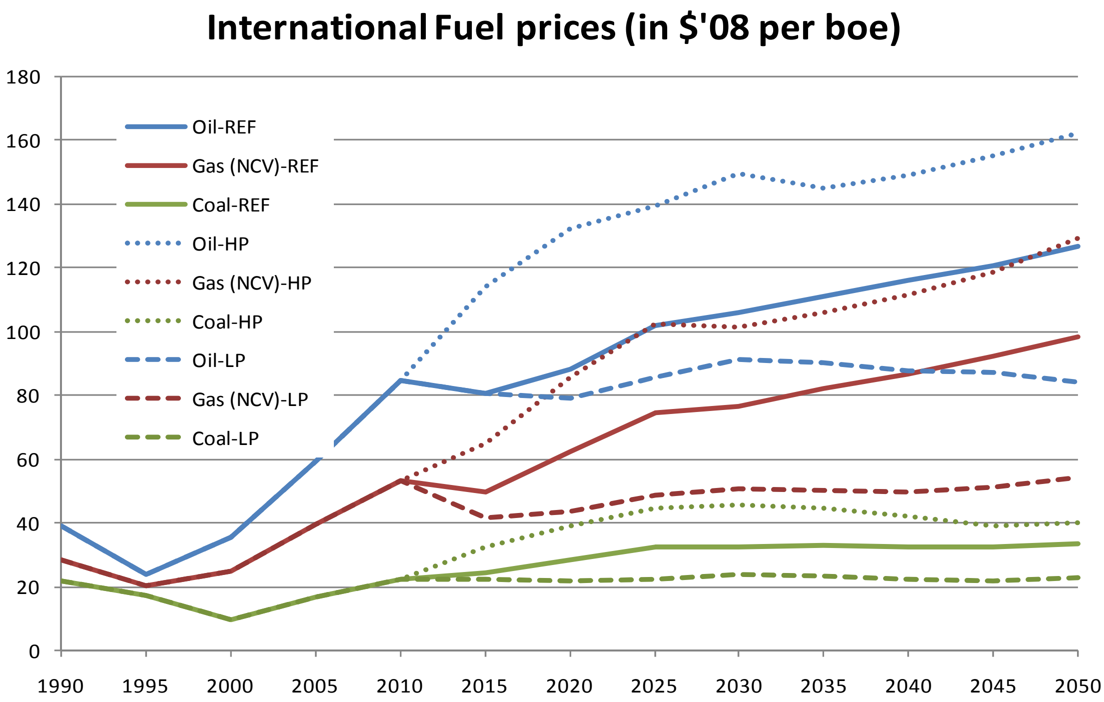
- There is currently great uncertainty on economic development including regarding excessive debts. It cannot be excluded that the recovery observed in 2009 and 2010 could prove to be relatively short lived, potentially leading to a "W shaped recession”).Whereas the reference scenario assumes a strong recovery of the world economy in the 2011-2014 period predicated on a rapid absorption of excess productive capacity (both capital and labour) and a strong resumption of investment in anticipation of fast growth in demand, developments could be less favourable. In particular, credit expansion could be hampered by the persistence of creditor exposure to uncertainty and increasing concern over the scope and timing of adjustments aimed at addressing imbalances (including sovereign debt). Consequently the investment boom may fail to materialize leading to some permanent loss of potential GDP (in the longer term world GDP is 7% lower in the modelled environment, which explains particularly low world fossil fuel prices).

- There is also uncertainty about energy resources and a more optimistic view could be adopted on this world energy price driver. In the low price variant, undiscovered conventional oil resources are set at their upper ten percentile value following USGS and PROMETHEUS assessments (in the reference scenario median values were used).
- In addition, the low price variant also assumes an increase in exploration activity outside the Gulf region as a response to security of supply concerns. This results in a more rapid translation of the resource basis into larger quantities of exploitable reserves. The main impact of this assumption is to bring forward the market easing emanating from greater resource abundance.
- The variant assumes rapid improvements in the knowledge and technologies associated with unconventional (shale) gas extraction. These in turn lead to enhanced interest in shale gas resources beyond North America leading to their more rapid incorporation into the exploitable resource base of some regions of the world. The assumptions concerning shale gas are the key driver for the high oil to gas price ratio that characterizes the low price variant.

Table 3: Energy import prices in the Reference scenario and low and high price variants

	2010	**2020**	**2030**	**2040**	**2050**
OIL					
Reference	84.6	88.4	105.9	116.2	126.8
High prices	84.6	132.2	149.3	148.8	162.3
%difference to Reference	*0.0%*	*49.5%*	*41.0%*	*28.1%*	*28.0%*
Low prices	84.6	78.8	91.5	87.9	83.9
%difference to Reference	*0.0%*	*-10.8%*	*-13.6%*	*-24.3%*	*-33.8%*
GAS					
Reference	53.5	62.1	76.6	86.8	98.4
High prices	53.5	85.5	101.5	111.6	129.0
%difference to Reference	*0.0%*	*37.7%*	*32.5%*	*28.5%*	*31.1%*
Low prices	53.5	43.7	50.9	49.9	54.1
%difference to Reference	*0.0%*	*-29.7%*	*-33.6%*	*-42.6%*	*-45.0%*
COAL					
Reference	22.6	28.7	32.6	32.6	33.5
High prices	22.6	39.3	45.7	42.0	40.0
%difference to Reference	*0.0%*	*37.0%*	*40.2%*	*28.9%*	*19.5%*
Low prices	22.6	21.9	23.8	22.2	23.1
%difference to Reference	*0.0%*	*-23.8%*	*-27.1%*	*-31.8%*	*-31.1%*

Figure 3: Sensitivity for international fuel prices



Similarly, to these sensitivities, the Current Policy Initiatives Scenario is based on slightly higher short term energy import prices reflecting 2010 developments.

1.3 Policy assumptions

Policy measures included in the Reference scenario are resumed in the following table:

	Measure		How the measure is reflected in PRIMES
Regulatory measures			
	Energy efficiency		
1	Ecodesign Framework Directive	Directive 2005/32/EC	Adaptation of modelling parameters for different product groups for Ecodesign and decrease of perceived costs by consumers for labelling (which reflects transparency and the effectiveness of price signals for consumer decisions). As requirements and labelling concern only new products, the effect will be gradual (marginal in 2010; rather small in 2015 up to full effect by 2030). The potential envisaged in the Ecodesign supporting studies and the relationship between cost and efficiency improvements in the model's database were cross-checked.
2	Stand-by regulation	Regulation No 1275/2008	
3	Simple Set-to boxes regulation	Regulation No 107/2009	
4	Office/street lighting regulation	Regulation No 245/2009	
5	Household lighting regulation	Regulation No 244/2009	
6	External power supplies regulation	Regulation No 278/2009	
7	TVs regulation (+labelling)	Regulation No 642/2009	
8	Electric motors regulation	Regulation No 640/2009	
9	Circulators[99] regulation	Regulation No 641/2009	
10	Freezers/refrigerators regulation (+labelling)	Regulation No 643/2009	
11	Labelling Directive	Directive 2003/66/EC	Enhancing the price mechanism mirrored in the model

[99] Circulator is an impeller pump designed for use in heating and cooling systems. Glandless standalone circulators and glandless circulators integrated in products are covered by this regulation.

12	Labelling for tyres	Regulation No 1222/2009	Decrease of perceived costs by consumers for labelling (which reflects transparency and the effectiveness of price signals for consumer decisions)
13	Energy Star Program (voluntary labelling program)		Enhancing the price mechanism mirrored in the model
14	Directive on end-use energy efficiency and energy services	Directive 2006/32/EC	National implementation measures are reflected
15	Buildings Directive	Directive 2002/91/EC	National measures e.g. on strengthening of building codes and integration of RES are reflected
16	Recast of the EPBD	Directive 2010/31/EU	New building requirements are reflected in technical parameters of the model, in particular through better thermal integrity of buildings and requirements for new buildings after 2020
17	Cogeneration Directive	Directive 2004/8/EC	National measures supporting cogeneration are reflected
	Energy markets		
18	Completion of the internal energy market (including provisions of the 3rd package)	http://ec.europa.eu/energy/gas_electricity/third_legislative_package_en.htm	The model reflects the full implementation of the Second Internal market Package by 2010 and Third Internal Market Package by 2015. It simulates liberalised market regime for electricity and gas (decrease of mark-ups of power generation operators; third party access; regulated tariffs for infrastructure use; producers and suppliers are considered as separate companies) with optimal use of interconnectors.
19	EU ETS directive	Directive 2003/87/EC as amended by Directive 2008/101/EC and Directive 2009/29/EC	The ETS carbon price is modelled so that cumulative cap for GHGs is respected[100]. The permissible total CDM amount over 2008-2020 is conservatively estimated at 1600 Mt. Banking of allowances is reflected The ETS cap is assumed to continue declining beyond 2020 as stipulated in legislation, however with an effective domestic emission decrease lower than the linear decrease rate of 1.74%) to result in a 50% cumulative decrease of actual emissions instead of 70% which could stem from the Directive as a maximum reduction of EU emissions if no use of international credits would be allowed beyond 2030[101]; currently no provision for the use of international credits post 2020 have been fixed and in the reference scenario world without global action, the higher ETS price might trigger

[100] For the allocation regime for allowances in 2010, the current system based on National Allocation Plans and essentially cost-free allowances is assumed, with price effects stemming from different investment and dispatch patterns triggered by need to submit allowances. For the further time periods, in the power sector there will be a gradual introduction of full auctioning, which will be fully applicable from 2020 onwards, in line with the specifications of the amended ETS directive.
For the other sectors (aviation and industry), the baseline follows a conservative approach which reflects the specifications in the directive on the evolution of auctioning shares and the provisions for free allocation for energy intensive sectors based on benchmarking.

[101] Compared with the Reference scenario to 2030, in the Reference scenario to 2050, the expectation of high ETS allowance prices in future and the possibility to bank allowances leads to higher prices in 2025 and 2030 than in the Reference scenario up to 2030.

			greater use of such credits, which would also be in greater supply with higher ETS prices. ETS prices are derived endogenously on the basis of allowances, international credits, emissions reflecting developments of energy consumption while taking account of banking.
20	RES directive	Directive 2009/28/EC	Legally binding national targets for RES share in gross final energy consumption are achieved in 2020; 10% target for RES in transport is achieved for EU27 as biofuels can be easily traded among Member States; sustainability criteria for biomass and biofuels are respected using the full detail of the biomass model linked to the PRIMES energy system model; cooperation mechanisms according to the RES directive are allowed and respect Member states indications on their "seller" or "buyer" positions. RES subsidies decline after 2020 starting with the phasing out of operational aid to new onshore wind by 2025; other RES aids decline to zero by 2050 at different rates according to technology. Increasing use of RES co-operation mechanisms is assumed and should help to reduce RES costs. Policies on facilitating RES penetration will continue.
21	GHG Effort Sharing Decision	Decision 406/2009/EC	National targets for non-ETS sectors are achieved in 2020, taking full account of the flexibility provisions such as transfers between Member States. After 2020, stability of the provided policy impulse but no strengthening of targets is assumed.
22	Energy Taxation Directive	Directive 2003/96/EC	Tax rates (EU minimal rates or higher national ones) are kept constant in real term. The modelling reflects the practice of MS to increase tax rates above the minimum rate due to i.a. inflation.
23	Large Combustion Plant directive	Directive 2001/80/EC	Emission limit values laid down in part A of Annexes III to VII in respect of sulphur dioxide; nitrogen oxides and dust are respected. Some existing power plants had a derogation which provided them with 2 options to comply with the Directive: either to operate only a limited number of hours or to be upgraded. The model selected between the two options on a case by case basis. The upgrading is reflected through higher capital costs.
24	IPPC Directive	Directive 2008/1/EC	Costs of filters and other devices necessary for compliance are reflected in the parameters of the model
25	Directive on the geological storage of CO2	Directive 2009/31/EC	Legal framework regulating the geological storage of CO2 allowing together with EEPR and NER300 CCS demonstration support (see below) economic modelling to determine CCS penetration
26	Directive on national emissions' ceilings for certain pollutants	Directive 2001/81/EC	PRIMES model takes into account results of RAINS/GAINS modelling regarding classical pollutants (SO2, NOx). Emission limitations are taken into account bearing in mind that full compliance can also be achieved via additional technical measures in individual MS.

27	Water Framework Directive	Directive 2000/60/EC	Hydro power plants in PRIMES respect the European framework for the protection of all water bodies as defined by the Directive, which limits the potential deployment of hydropower and might impact on generation costs.
28	Landfill Directive	Directive 99/31/EC	Provisions on waste treatment and energy recovery are reflected
	Transport		
29	Regulation on CO2 from cars	Regulation No 443/2009	Limits on emissions from new cars: 135 gCO2/km in 2015, 115 in 2020, 95 in 2025 – in test cycle. The 2015 target should be achieved gradually with a compliance of 65% of the fleet in 2012, 75% in 2013, 80% in 2014 and finally 100% in 2015. Penalties for non-compliance are dependent on the number of grams until 2018; starting in 2019 the maximum penalty is charged from the first gram.
30	Regulation EURO 5 and 6	Regulation No 715/2007	Emissions limits introduced for new cars and light commercial vehicles
31	Fuel Quality Directive	Directive 2009/30/EC	Modelling parameters reflect the Directive, taking into account the uncertainty related to the scope of the Directive addressing also parts of the energy chain outside the area of PRIMES modelling (e.g. oil production outside EU).
32	Biofuels directive	Directive 2003/30/EC	Support to biofuels such as tax exemptions and obligation to blend fuels is reflected in the model The requirement of 5.75% of all transportation fuels to be replaced with biofuels by 2010 has not been imposed as the target is indicative. Support to biofuels is assumed to continue. The biofuel blend is assumed to be available on the supply side.
33	Implementation of MARPOL Convention ANNEX VI	2008 amendments - revised Annex VI	Amendment of Annex VI of the MARPOL Convention reduce sulphur content in marine fuels which is reflected in the model by a change in refineries output
34	Regulation Euro VI for heavy duty vehicles	Regulation (EC) No 595/2009	Emissions limits introduced for new heavy duty vehicles.
35	Regulation on CO2 from vans[102]	Part of the Integrated Approach to reduce CO2 emissions from cars and light commercial vehicles.	Limits on emissions from new LDV: 181 gCO2/km in 2012, 175 in 2016, 135 in 2025 – in test cycle
Financial support			
36	TEN-E guidelines	Decision No 1364/2006/EC	The model takes into account all TEN-E realised infrastructure projects
37	EEPR (European Energy Programme for Recovery) and NER 300 (New entrance reserve) funding programme	For EEPR: Regulation No 663/2009; For NER300: EU Emissions Trading Directive 2009/29/EC	Financial support to CCS demonstration plants; off-shore wind and gas, innovative renewables and electricity interconnections is reflected in the model. For CCS, - the following envisaged

102 On 28 October 2009 the European Commission adopted a new legislative proposal to reduce CO2 emissions from light commercial vehicles (vans). The draft legislation is closely modelled on the legislation on the CO2 emissions from passenger cars (Regulation 443/2009) and it is part of the Integrated Approach taken by the Commission in its revised strategy to reduce CO2 emissions from cars and light commercial vehicles (COM(2007) 19 final). Not including this proposal in the 2050 Reference scenario could lead to an increased bias towards vans, which is not justified given the likelihood of its adoption towards the end of 2010/beginning of 2011.

		Article 10a(8), further developed through Commission Decision 2010/670/EU[103]	demonstration plants are taken into account for commissioning in 2020: Germany 950 MW (450MW coal post-combustion, 200MW lignite post-combustion and 300MW lignite oxy-fuel), Italy 660 MW (coal post-combustion), Netherlands 1460 MW (800MW coal post-combustion, 660MW coal integrated gasification pre-combustion), Spain 500 MW (coal oxy-fuel), UK 3400 MW (1600MW coal post-combustion, 1800MW coal integrated gasification pre-combustion), Poland 896 MW (306MW coal post-combustion, 590MW lignite post-combustion); investment in further plants depends on carbon prices
38	RTD support (7th framework programme- theme 6)	energy research under FP7	Financial support to R&D for innovative technologies such as CCS, RES, nuclear and energy efficiency is reflected by technology learning and economies of scale leading to cost reductions of these technologies
39	State aid Guidelines for Environmental Protection and 2008 Block Exemption Regulation	Community guidelines on state aid for environmental protection	Financial support to R&D for innovative technologies such as CCS, RES, nuclear and energy efficiency is reflected by technology learning and economies of scale leading to cost reductions of these technologies
40	Cohesion Policy – ERDF, ESF and Cohesion Fund		Financial support to national policies on energy efficiency and renewables is reflected by facilitating and speeding up the uptake of energy efficiency and renewables technologies.
41	Rural development policy - EAFRD	Council Regulation (EC) No. 1698/2005	Financial support for supply and use of renewable energy to farmers and other actors in rural areas, financial support to investments increasing energy efficiency of farms
National measures			
42	Strong national RES policies		National policies on e.g. feed-in tariffs, quota systems, green certificates, subsidies and other cost incentives are reflected
43	Nuclear		Nuclear, including the replacement of plants due for retirement, is modelled on its economic merit and in competition with other energy sources for power generation except for MS with legislative provisions on nuclear phase out. Several constraints are put on the model such as decisions of Member States not to use nuclear at all (Austria, Cyprus, Denmark, Estonia, Greece, Ireland, Latvia, Luxembourg, Malta and Portugal) and closure of existing plants in some new Member States according to agreed schedules (Bulgaria 1760 MW, Lithuania 2600 MW and Slovakia 940 MW). The nuclear phase-out in Belgium and Germany is respected while lifetime of nuclear power plants was extended to 60 years in Sweden. Nuclear investments are possible in Bulgaria, the Czech Republic, France, Finland, Hungary, Lithuania, Romania, Slovakia, Slovenia, Spain and UK

[103] NER covers 300 million allowances set aside in the new entrants reserve of the EU ETS for the co-financing of commercial demonstration projects of environmentally safe CCS as well as innovative RES technologies

			For the modelling the following plans on new nuclear plants were taken into account: Bulgaria (1000 MW by 2020 and 1000 MW by 2025), Finland (1600 MW by 2015), France (1600 MW by 2015 and 1600 MW by 2020), Lithuania (800 MW by 2020 and 800 MW by 2025), Romania (706 MW by 2010, 776 MW by 2020 and 776 MW by 2025), Slovakia (880 MW by 2015). Member States experts were invited to provide information on new nuclear investments/programmes in spring 2009 and commented on the PRIMES baselines results in summer 2009, which had a significant impact on the modelling results for nuclear capacity.

In addition to these measures, the Current Policy Initiatives Scenario includes the following policies and measures:

Area	**Measure**	**How it is reflected in the model**
Internal market		
1	Effective transposition and implementation of third package, including the development of pan-European rules for the operation of systems and management of networks in the long run	The modelling approach mirrors completion of the internal market, but has to account for existing interconnector limitations. Better market integration is reflected by having higher net transfer capacities in the near future and additional interconnectors in the longer term which lead to higher price convergence in multi-country market coupling in both electricity and gas markets (for details see below). In the gas market, more diversification (see also point 1) and higher degree of competition lead to lower oligopoly mark-ups and lower prices.
2	Regulation on security of gas supply (N-1 rule, necessity for diversification)	Compliance with N-1 rule and the necessity for diversification induce higher costs in the model for gas companies.
3	Regulation on Energy market integrity and transparency (REMIT)	The model simulates well functioning energy markets
Infrastructure		
4	Facilitation policies (faster permitting; one stop shop)	All these policies induce shorter lead times and slightly lower costs allowing faster infrastructure deployment.
5	Infrastructure instrument	More funding available from the EU budget
6	Updated investments plans based on ENTSO-e Ten Year Network Development Plan	Interconnection capacity reflects projects in the TYNDP by 2020.
7	Smartening of grids and metering	Smart grids and meters will lead to higher costs mainly for distribution but will allow for more energy efficiency in the system and decentralised RES
Energy efficiency	measures proposed in the Energy efficiency Plan – implementation compared to scenario 3[104] less vigorously and at a more moderate	

[104] All measures included in the scenario underpinning the IA for the Energy efficiency Directive are included. Energy (saving) results can differ given different framework conditions flowing from all the additional assumptions above. Moreover, it should be considered that scenario 3 Energy Efficiency should show contrasted results in terms of energy consumption so that a significant individual contribution of energy

	rate	
8	Obligation for public authorities to procure energy efficient goods and services	Cost perception parameters for non market service sector adapted accordingly
9	Planned Ecodesign measures (boilers, water heaters, air-conditioning, etc)	Adaptation of modelling parameters for different product groups. As requirements concern only new products, the effect will be gradual (rather small in 2015 and up to full effect by 2030/2035 as e.g. boilers can have a very long lifetime)
10	High renovation rates for existing buildings due to better/more financing and planned obligations for public buildings	Change of drivers (ESCOs, energy utilities obligation in point 13, energy audits point 14) influence stock – flow parameters in the model reflecting higher renovation rates, with account being taken of tougher requirements for public sector through specific treatment of the non-market services sector
11	Passive houses standards after 2020 (already in the Reference scenario)	Higher penetration of passive houses standards compared to the Reference scenario (around 30-50 KWh/m2 depending on a country which might to a large extent be of renewable origin)
12	Greater role of Energy Service Companies	Enabling role of ESCOs is reflected via altered economic parameters leading to more energy efficient choices (see also point 10)
13	Obligation of utilities to achieve energy savings in their customers' energy use of 1.5% per year (until 2020)	Induce more energy efficiency mainly in residential and tertiary sectors by imposing an efficiency value for grid bound energy sources (electricity, gas, heat)
14	Mandatory energy audits for companies	Induce more energy efficiency in industry (see also point 10)
15	Obligation that, where there is a sufficient demand authorisation for new thermal power generation is granted on condition that the new capacity is provided with CHP; Obligation for electricity DSOs to provide priority access for electricity from CHP; Reinforcing obligations on TSOs concerning access and dispatching of electricity from CHP	To a large extent already reflected in the Reference scenario 2050 Further facilitation of CHP penetration in the model
16	Obligation that all new energy generation capacity reflects the efficiency ratio of the best available technology (BAT), as defined in the Industrial Emissions Directive	High energy efficiency to a large extent already reflected in the Reference scenario 2050 as a response to ETS carbon prices; energy efficiency improves furthermore in power generation along with new investment from more efficient vintages
17	Other measures (better information for consumers, public awareness, training, SMEs targeted actions)	Induce faster energy efficiency improvements
Nuclear		
19	Nuclear Safety Directive	Harmonisation with international standards
20	Waste Management Directive	Cost for waste management reflected in generation costs
21	Consequences of Japan nuclear accident	Stress tests and other safety measures reflected through higher costs for retrofitting (up to 20% higher generation costs after lifetime extension compared with Reference scenario) and introduction of risk premium for new nuclear power plants. Nuclear determined on economic grounds, subject

efficiency towards decarbonisation can be identified. Scenario 1bis includes some adjustments to reflect somewhat less optimistic expectations for penetration of energy efficiency products/renovation of buildings.

		to non nuclear countries (except for Poland) remaining non-nuclear
CCS		
22	Slower progress on demonstration plants	Downward revision of planning for some CCS demonstration plants compared to the Reference case; some plants might be commissioned later depending on carbon prices. Change regarding potential storage sites in BE and NL.
Oil and gas		
23	Offshore oil and gas platform safety standards	Standards slightly increase production costs for oil and gas in the EU
Taxation		
24	Energy taxation Directive (revision 2011)	Changes to minimum tax rates for heating and transport sectors reflect the switch from volume-based to energy content-based taxation and the inclusion of a CO_2 tax component. Where Member States tax above the minimum level, the current rates are assumed to be kept unchanged. For motor fuels, the relationships between minimum rates are assumed to be mirrored at national level even if the existing rates are higher than the minimum rates. Tax rates are kept constant in real terms.
Transport		
25	A revised test cycle to measure CO_2 emissions under real-world driving conditions (to be proposed at the latest by 2013) [105]	Implementation of CO_2 standards for passenger cars (95 g CO_2/km) by 2020. Starting with 2020 assume autonomous efficiency improvements as in the Reference scenario.
26	Update of the CO_2 standards for vans according to the adopted regulation[106]	Implementation of CO_2 standards for vans (175 g of CO_2 per kilometre by 2017, phasing in the reduction from 2014, and to reach 147g CO_2/km by 2020).
Other parameters		
Energy import prices		Short-term increase to reflect the evolution of prices up to 2010
Technology assumptions	Higher penetration of EVs reflecting developments in 2009-2010 national support measures and the intensification of previous action programmes and incentives, such as funding research and technology demonstration (RTD) projects to promote alternative fuels.	Slightly higher penetration of EVs Assumed specific battery costs per unit kWh in the long run: 390-420 €/kWh for plug-in hybrids and 315-370 €/kWh for electric vehicles, depending on range and size, and other assumptions on critical technological components[107].

[105] In Europe, the New European Driving Cycle is the official driving cycle used for vehicle type approval. According to a study carried out for the Commission in 2009, there is some discrepancy (typically 10-20%) between the fuel consumption as measured on the NEDC and that in real world driving. Source: Sharpe, R.B.A. (2009) Technical options for fossil fuel based road transport, Paper produced as part of contract ENV.C.3/SER/2008/0053 between European Commission Directorate-General Environment and AEA Technology plc; http://eutransportghg2050.eu/cms/assets/EU-Transport-GHG-2050-Paper-1-Technical-options-for-f-fuel-road-transport-11-02-10.pdf, p.9

[106] Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011, setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO2 emissions from light-duty vehicles

[107] International Energy Agency (2009), Transport, Energy and CO2: Moving Towards Sustainability.

1.4 Assumptions about energy infrastructure development

Regarding **infrastructure** representation, the scope of the modelling was increased by undertaking the determination of electricity interconnectors in a two stages approach. The aim is to represent market integration cost-effectively given many different scenarios modelled. The purpose of stage 1 is to determine electricity trade in the internal market based on a simpler version of PRIMES determining the equilibrium with all countries linked through endogenous trade, which due to its great technology detail on power generation requires very long computing times for each run. Stage 2 concerns the fully detailed modelling on the basis of the outcome of stage 1. The very long computing times for each model run under endogenous trade require a cost-effective approach, given that many iterations need to be performed between demand and supply and for meeting carbon targets. Running all countries in parallel in stage 2, involving many iterations, ensures delivery of modelling results in time.

Data about NTCs and interconnection capacities were taken from ENTSOe databases. Information on new constructions was taken from the latest “Ten-year network development plan 2010-2020”, complemented, where necessary, with information from the Nordic Pool TSOs and the Energy Community (for South East Europe). Some of the planned new constructions would justify increase of NTCs values until 2020, as mentioned in the ENTSOe’s TYNDP document. Other mentioned new constructions regard directly the building of new interconnection lines which are introduced as such in the model database.

Market integration leads to more electricity trade, which in turn needs infrastructure that is also dealt with in the modelling. Several test modelling runs were undertaken. It turned out that for the Reference and Current Policy Initiatives scenarios, the 2020 interconnection capacity would allow for most intra-EU electricity trade up to 2050 provided that a few identified bottlenecks would be dealt with. Such areas are the southern and eastern connections of Germany, the area linking Italy, Austria and Slovenia, the linkages of Balkans with northern neighbours and the linkages within Balkans. Some NTC additions should be also made for the linkages Denmark-Sweden and Latvia-Estonia. With lower electricity demand due to the assumed strong energy efficiency policies, these results also hold for the Current Policy Initiatives scenario.

Other infrastructure is dealt with in a less sophisticated way given that this is not so much in the focus of the energy system model at the European level. For CCS infrastructure (CO2 storage and transport) as well as for the sites of power plants, e.g. nuclear or RES installations (the sites - not the generation as such, see below) non-linear cost supply curves have been applied that take account of increasing costs, leading to higher costs once the most suitable and cheapest sites have been used.

Details on the modelling approach taken can be found in the Attachment 2 on interconnections.

1.5 Technology assumptions

Technology parameters are exogenous in the PRIMES modelling and their values are based on current databases, various studies[108] and expert judgement and are regularly compared to other leading institutions. Technologies are assumed to develop over time and to follow learning curves which are exogenously adjusted to reflect the technology assumptions of a scenario. For some technologies, in particular, for off-shore wind and nuclear, the database of

[108] NEMS database and reports, IEA studies, industry surveys, EU project reports, etc.

realised projects is very limited which can lead to significant differences depending on how many projects and what projects were included and where projects are being built.

The energy efficiency and other characteristics of the existing stock for a technology in a given period depend on previous investments. This ensures that as in real life changes in the characteristics of the technology stock happen only gradually depending on the type and magnitude of new investment as well as the rate of retirement of obsolete equipment. The market acceptance of a technology is also modelled and depends on the maturity of a technology; the more mature a technology the higher its market acceptance. Nuclear is however a special case driven mainly by political considerations at government levels and acceptance by citizens.

In order to ensuring comparability across scenarios, technology assumptions regarding capital and operational costs as well as technology performance over time have to remain the same across scenarios, except for cases, in which there were specific policies on technology progress (e.g. targeted support to one specific technology). In addition to these genuine technology parameters, the uptake of technologies is also influenced by other modelling parameters reflecting policy intensity, such as carbon and renewables values; these are discussed in later chapters. Current trend and decarbonisation scenarios differ regarding enabling policies, impacting also on technology uptake, as well as economies of scale in technology deployment, bringing lower energy costs. Technology specific parameters as such remain the same across scenarios.

The modelling cycle ending with the Energy Roadmap started in 2009 with the update of the Baseline, meaning that capital costs assumptions for 2010 and their evolution up to 2050 are based on information available in 2009/2010.. The Low Carbon Economy Roadmap and the Transport White Paper of spring 2011 were based on the same technology assumptions. It is clear that markets and technology costs as well as performance parameters evolve over time. Therefore, such assumptions need periodical update, which will be done again for the next modelling cycle starting in 2012.

Power generation

Power generation technologies are characterised by capital costs, variable and fixed operation costs and by efficiencies. These characteristics are assumed to change over time due to technological improvements (impacting predominantly on capital costs). The assumptions for the Reference scenario for 2010 have been compared to other studies (e.g. IEA[109] and US DOE[110]), where possible[111]; all costs have been transformed into EUR[112].

As can be seen in Figure 4 the capital costs in PRIMES are within the range of other studies.

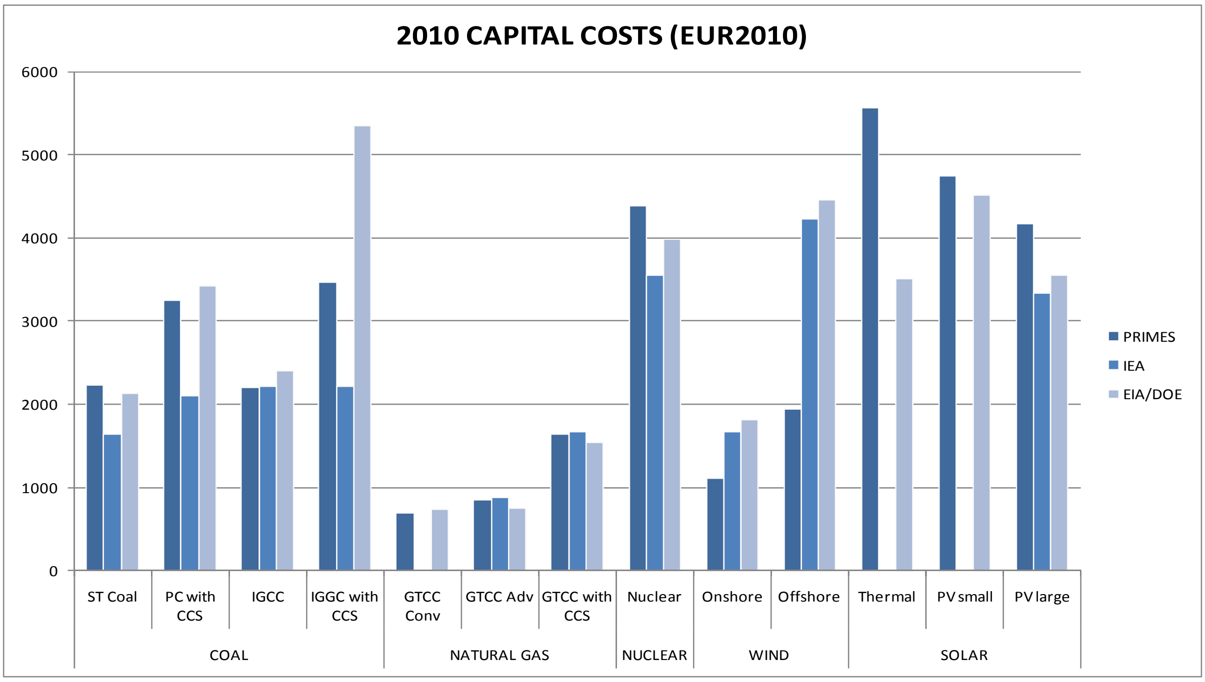
109 IEA (2010), Projected Costs of Generating Electricity, 2010 Edition. IEA, NEA, OECD, Paris

110 Energy Information Administration, Annual Energy Outlook 2010, December 2009, DOE/EIA-0383 (2009)

111 Definitions in the studies may not totally overlap, in particular for fixed and variable costs.

112 The exchange rates used are: 1.34USD/EUR (USD2010 to EUR2010).

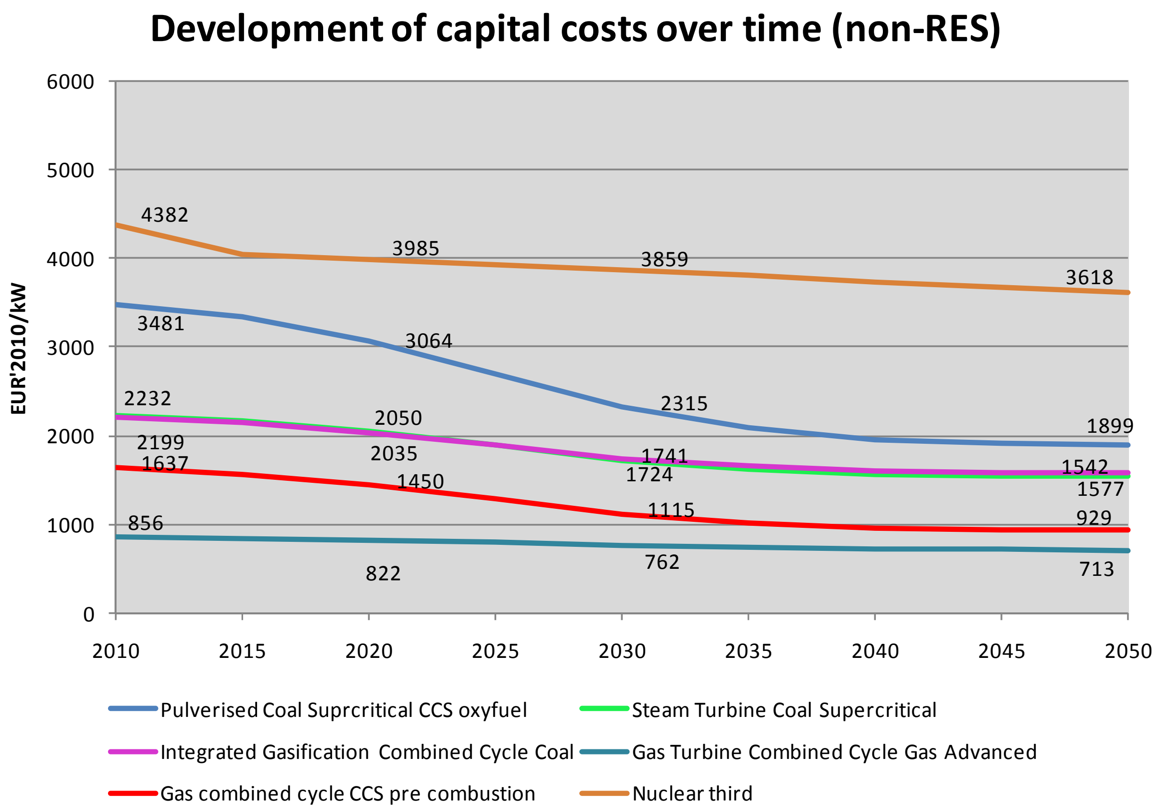
Figure 4: Capital costs in EUR/kWh in 2010[113]

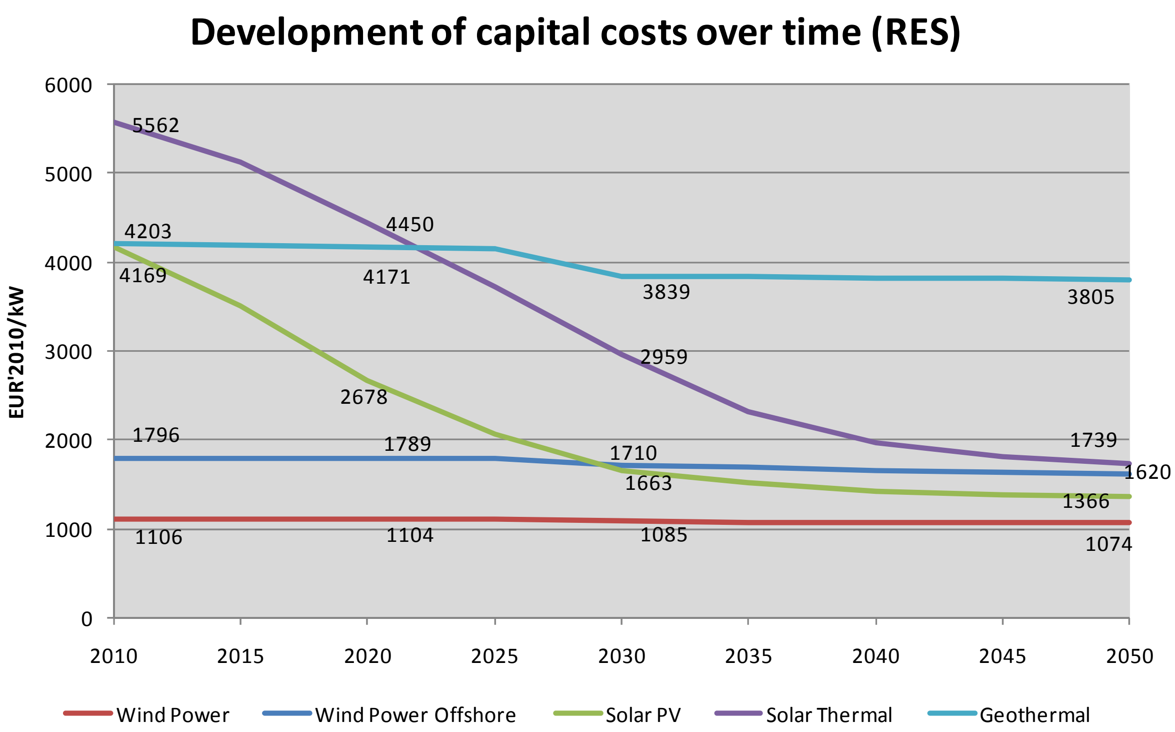


The costs of technologies evolve over time in the Reference scenario reflecting learning curves and economies of scale. There are ample possibilities for solar technologies, both thermal and PV, to see costs decreasing over time, which is also the case for CCS technologies. These are not yet mature technologies and can therefore still follow steep learning curves. By comparison, the possibilities of wind onshore to further decrease its costs are rather limited with some potential still existing for small wind turbines., Figure 5 shows cost developments for mainstream onshore wind at medium size. As can also be seen in that figure, capital costs for off-shore wind can be expected to decrease significantly over time.

113 Abbreviations in the figure: ST Coal: Steam Turbine Coal; CCS: Carbone Capture and Storage; PC with CCS: pulverised coal with CCS; IGCC: Integrated Gasification Combine Cycle; GTCC: Gas Turbine Combined Cycle; PV: photovoltaic.

Figure 5: Development of capital costs over time in the Reference scenario





The effective cost of a technology depends also on subsidies that may be paid by governments for environmental reasons to encourage specific innovative technologies that may require state aids for some time. In the case of renewables, Member States have support schemes that encourage the uptake of renewables technologies depending often on cost differences with conventional power generation technologies. This implies dependence of such aids on the progress in the cost reduction for renewables technologies, which are becoming increasingly cost competitive over time.

The Roadmap modelling assumes that such existing operational aid to RES for power generation is being phased out according to the maturity of the individual technology subgroups. In the longer term, only innovative and still costly RES technologies, such as solar PV, wave, tidal and off-shore wind at difficult sites, would receive aids. While for the more mature technologies (onshore wind) such aid is assumed to have been phased out rather early in the modelling (by 2025), the phasing-out of operational aid is completed by 2050 for other technologies. As RES technology costs come down, sometimes ahead of expectations, governments curtail the aid they grant.

In any case, the operational aids modelled only foster the uptake of RES technologies that are not yet fully commercial. Renewables support is modelled via support to capital costs. This support is relevant only for the investment decision but does not reduce electricity costs, given that the full costs of RES deployment are paid for by electricity consumers. In a large number of Member States this is currently done via feed-in tariffs, the salient features of which (all electricity consumers pay for the support to specific technologies) are captured by the electricity modelling undertaken in these scenarios. It is important to note that the current trend and decarbonisation scenarios have the same levels of operational aids that decrease over time.[114]

Distributed Heat and Steam

Distributed heat in PRIMES can come either from CHP or district heating boilers. There are several technologies to produce steam, but distribution technologies are rather standard. For CHP there are ten different technologies that are applicable to different power generation technologies; the CHP technologies relate to the different technical options to extract the steam e.g. extraction, back-pressure or condensing technologies. The CHP technologies are considered mature, therefore no new learning effects are assumed. The higher penetration of CHP technologies in the different scenarios is based on policy drivers.

Demand side technologies

Demand side technologies are mainly related to buildings, appliances, industrial equipment and transport vehicles. The penetration of new technologies can have important effects on energy efficiency improvement as well as on fuel switching. Technology parameters are exogenous with assumptions being based on results of various studies. The PRIMES data is compared regularly to other sources. For electric appliances PRIMES technologies were compared to the EuP Preparatory studies set out in directive 2005/32/EC and to the IEA Energy Technology Perspectives 2008, as well as the "Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries Final Report"[115]. The comparison proved that the assumptions taken in the PRIMES model are comparable to the developments of BAT and BNAT available from the EuP preparatory studies.

[114] Greater deployment of RES or other low carbon technologies in decarbonisation scenarios is due to carbon prices/values as well as other specific changes (including higher RES values) depending on the scenario, but does not involve greater operational aid.

[115] Eichhammer et al. (2009), Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries Final Report, Fraunhofer ISI and ENERDATA and ISIS and Technical University Vienna and WI, March 2009.

There is a very large number of different energy uses and technologies to provide the energy services (heating and cooling, light, motion, communication, etc) that consumers want when purchasing equipment and energy carriers.

In the PRIMES modelling, consumers always have the possibility of choosing between several vintages of the same technology, which are characterised by different prices and efficiencies. Throughout the projection period technologies become more mature and their market acceptance may grow, due to increased market maturity and policies.

Figure 6: Examples of developments of electric appliances in PRIMES compared to other literature sources[116]

Appliance	Source	Base Case	Improved	BAT	BNAT
Washing machine	EuP and IEA	0.998kWh/cycle 443EUR		-10% (+25% cost)	Technical performance limit might soon be reached
	PRIMES	1.57kWh/cycle 582EUR	40% improvement,	-50% (+32% cost)	further -5%, at 25% cost increase
Lighting	EuP			Residential: - Services: -70% Street: -30%	LEDs and OLEDs
	PRIMES		-26% at 30% cost	-80% (+250% cost)	further -2% at 35% cost
Entertainment /office equipment	EuP			TVs: -20% Computers: -65 to -75%	TVs:-30 to -50% compared to current Computers: software and consumer behaviour
	PRIMES	815EUR	-10% at 32% cost	further -10% (+32% cost)	further -5%, at 25% cost increase
Boilers (Water heating)	EuP (Gas?)		30-40%	60%	
	Primes (Gas)	500-1500EUR	21%	42% (add. Inv. Cost 100%)	47%
Boilers (Central heating)	EuP (Gas?)			30%-40%	
	Primes (Gas)	1000-3000EUR	9%	23% (add. Inv. Cost. 49%)	30%
Air conditionining	EuP			-57%	
	Primes (Elec)	500-1500EUR		-47% (add. Inv. Cost 61%)	

The technologies in the above table only show a small variety of the technologies available in the model; further technologies and fuels for the technologies are available both for the services and residential demand as well as for industry and agriculture. The data has been

116 Due to the variety of appliances available (in particular for boilers) the values here are chosen as examples and due to lack of data it is possible that the typical appliances of the different sources do not correspond entirely to the PRIMES technology.

compiled and updated over the years based on numerous sources including data from NEMS, the MURE database, industrial surveys, EU project reports and IEA studies.

For households PRIMES includes five different dwelling types, differentiated according to the main energy pattern[117] which each have energy services provided to them such as: space heating, water heating, cooking, cooling, lighting and other needs. Because of the very large variety of housing types both within and between countries, PRIMES uses curves for the possibilities of changes in thermal integrity of buildings relating marginal costs with energy efficiency improvements. Specific numbers for a typical household/dwelling type can therefore not be provided explicitly.

Transport

For transport vehicles the same mechanisms apply as for appliances; a consumer can choose different vintages of the same kind of vehicle at different costs and efficiency. Also for transport, a comparison with a variety of literature sources was carried out, which proves that the estimates of PRIMES are in line with other estimates.

[117] Please refer to the PRIMES model description available at : http://www.e3mlab.ntua.gr/e3mlab/PRIMES%20Manual/The_PRIMES_MODEL_2010.pdf

Table 4: Comparison of costs and efficiencies from different literature sources with PRIMES[118]

Vehicle type	Source		Base case technology	Improved technology	Advanced technology	More advanced technology
ICE gasoline	McKinsey 2009	efficiency [l/100km]			6.1	
		cost [EUR]			22252	
	IEA 2009	efficiency [l/100km]	7.0	5.6	4.3	
		cost [EUR]		21336	22169	
	PRIMES	efficiency [l/100km]	*10.0*	8.0	6.3	5.7
		cost [EUR]	*19252*	22461	26739	30750
	DOE 2010	efficiency [l/100km]	*8.99*		5.6	
		cost [EUR]				
	EPA 2005	efficiency [l/100km]		7.2	5.3	
		cost [EUR]		19964	20570	
ICE diesel	McKinsey 2009	efficiency [l/100km]			4.5	
		cost [EUR]			23461	
	IEA 2009	efficiency [l/100km]	7.0			3.9
		cost [EUR]			24295	25961
	PRIMES	efficiency [l/100km]	9.7	7.5	5.9	5.4
		cost [EUR]	21795	27927	32714	37239
	EPA 2005	efficiency [l/100km]			5.8	
	FEV/EPA	cost [EUR]			23786	
		efficiency [l/100km]			6.5	
	ORNL	cost [EUR]			24344	
	WBSCD 2004	efficiency [l/100km]		8.0		
HEV gasoline	McKinsey 2009	efficiency	7.0	3.92		
		cost [EUR]		22586		
	IEA 2009	efficiency	6.7	5.5	5.0	3.2
		cost [EUR]	21336	21752	23002	26452
	PRIMES	efficiency	6.3	5.0	3.9	3.6
		cost [EUR]	27167	30563	35037	38742
	EPA 2005	efficiency		4.9		
	EPRI	cost [EUR]		21752		
		efficiency		6.0		
	ORNL	cost [EUR]		21935		
	WBCSD 2004	efficiency		7.5	6.3	
HEV diesel	McKinsey 2009	efficiency [l/100km]	7.0	5.6		
		cost [EUR]		22586		
	IEA 2009	efficiency [l/100km]	6.0	5.5	4.7	2.7
		cost [EUR]	21752	23419	24252	26752
	PRIMES	efficiency [l/100km]	6.3	5.0	3.9	3.6
		cost [EUR]	26953	30322	34761	38438
	EPA 2005	efficiency [l/100km]			2.9	
		cost [EUR]			23375	
	WBCSD 2004	efficiency [l/100km]	7.6	6.4		
EV	McKinsey 2009	efficiency [l/100km]			3.0	1.5
		cost [EUR]			49252	24086
	IEA 2009	efficiency [l/100km]			2.8	2.8
		cost [EUR]			29669	33836
	PRIMES	efficiency [l/100km]	3.7	3.5	3.2	2.9
		cost [EUR]	32292	36329	41647	46052
	WBCSD 2004	efficiency				2.0

The amounts of biofuels in the fuel mix of the Reference scenario are determined by the relative costs of the fuels taking account of tax differentials and biofuel quotas. The PRIMES model currently does not distinguish between dedicated biofuel vehicles and vehicles that allow only for blending; the fuel and vehicle stock mix simulate the inclusion of dedicated vehicles implicitly.

[118] Note: for EV 1l/100km is approximately 8.5kWh/100km; an exchange rate USD to EUR of 1.2USD/EUR has been used.

The Current Policy Initiatives Scenario relies on the same technology assumptions besides nuclear in power generation which has been revised upwards reflecting the follow-up to the Japanese nuclear accident.

1.6 Other assumptions

Discount Rates

The PRIMES model is based on individual decision making of agents demanding or supplying energy and on price-driven interactions in markets. The modelling approach is not taking the perspective of a social planner and does not follow an overall least cost optimization of the energy system. Therefore, social discount rates play no role in determining model solutions. However, social discount rates can be used for ex post cost evaluations.

Discount rates pertaining to individual agents play an important role in their decision behaviour. Agents' decisions about capital budgeting involve the concept of cost of capital, which is depending on the sector - weighted average cost of capital (for firms) or subjective discount rate (for individuals). In both cases, the rate used to discount future costs and revenues involves a risk premium which reflects business practices, various risk factors or even the perceived cost of lending. The discount rate for individuals also reflects an element of risk averseness.

Table 5: Discount rates for the different actors[119]

Discount rates	
Industry	12%
Private individuals	17.5%
Tertiary	12%
Public transport	8%
Power generation sector	9%

Degree days against the background of climate change

The heating degree days, reflecting climate conditions, are kept constant at the 2000 level, which is higher than the long term average without assuming any trend towards further warming. The degree days in 2000 were fairly similar to the ones in 2005. This simplification allows comparison of recent statistics with the projection figures, without the need for climate correction.

There are also other energy related impacts from climate. However, future climate change depends on future emissions worldwide, atmospheric concentration and the sensitivity of the climate system to such concentration increases. Future developments in these areas are surrounded by substantial uncertainty. Given this uncertainty and the focus of this impact assessment on the various energy system impacts this quantitative analysis has assumed constant climate conditions over time. This simplification should be borne in mind when considering the following detailed results under constant climate, which is likely to change more, the more pronounced the global emission increase. All the decarbonisation scenarios in Part B assume meeting the climate targets, which are expected to prevent dangerous climate change. However, even when temperature changes are limited to 2 degrees Celsius, some

[119] The discount rate for private individuals includes risk aversion; risk premiums are added for other actors and are technology specific.

climate impacts will occur. A literature review on climate change impacts in the European energy supply sector[120] has identified the following main impacts:

- Cooling water constraints for thermal power generation (especially during heat waves), with nuclear appearing to be particularly strongly affected[121]
- Damage to offshore or coastal production facilities due to sea level rise and storm surges
- Damage to transmission and distribution lines due to storm events, flooding
- Lower predictability of hydropower availability
- Affected yield in renewable energy sector (hydropower in Southern Europe, possibly biofuels due to diseases and forest fires, possibly faster biomass plant growth in certain areas)
- Melting permafrost affecting energy production and distribution in cold climates
- Damages and output constraints in wind energy due to storms and increased average wind speed

In addition, changes in temperature might lead to changes in energy demand patterns for heating and cooling.

It can hence be expected that decarbonisation has also positive economic impacts with regard to energy security and competitiveness by avoiding parts of the damage and adaptation costs in the energy system due to climate change.

In any case, given our lack of knowledge – perhaps for a considerable time to come - about how the EU 2050 GHG emission objective will be met and how global GHG emission will develop over time and therefore lacking information on future atmospheric concentrations and their impacts on temperatures in the Member States, the simplifying assumption has been made in this analysis that heating degree days remain constant.

Exchange rates

All monetary values are expressed in constant, 2005, terms (without inflation). The economic modelling in PRIMES is based on euros. The dollar exchange rate for current money changes over time; it starts at the value of 1.45$/€ in 2009 and is assumed to decrease to 1.25 $/€ by 2020 and to remain at that level for the remaining period.

[120] As part of the European Commission contract "Climate proofing EU policies".
[121] Interim results of the FP7 project "European RESPONSES to climate change"

2. RESULTS

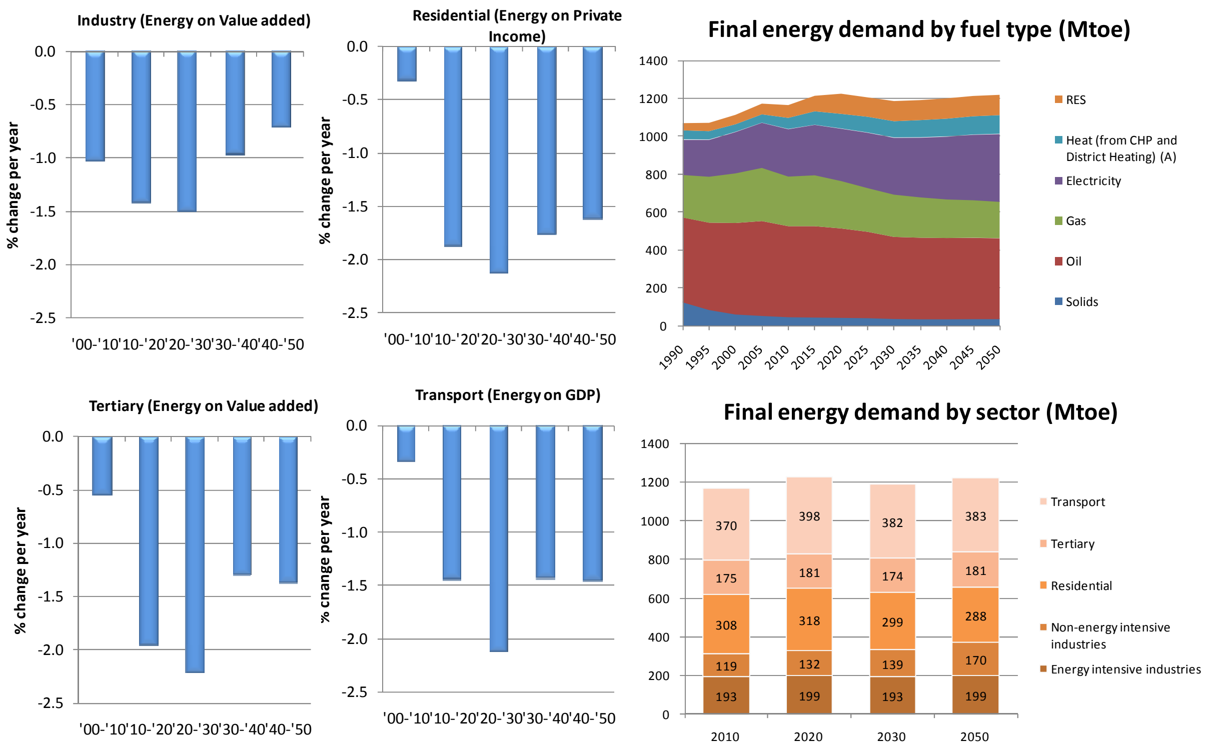
2.1 Reference scenario

Energy consumption and supply

Primary energy consumption peaked in 2006 at a level only marginally different from the year before. Given that 2005 numbers in the PRIMES output have been fully calibrated to 2005 Eurostat energy statistics, the following comparisons start from 2005, being virtually the peak year of energy consumption so far[122]. With ongoing energy efficiency policies – even in the absence of any further policy intensification as depicted in the Reference case- total energy demand decreases slightly up to 2050 (-4% from 2005). This is despite post-crisis economic growth leading to a doubling of GDP between 2005 and 2050 (on an EU-27 average of 1.6 % per year). Therefore, energy intensity drops considerably with one unit of GDP in 2050 requiring only less than half the energy needed in 2005.

Final energy consumption continues rising until 2030, after which demand stabilises as more efficient technologies have by then reached market maturity and the additional energy efficiency of the appliances is sufficient to compensate for increased demand for energy services (heat, light, motion, etc). The share of sectors remains broadly stable with transport staying the biggest single consumer accounting for 32% in 2050; the industrial share increases slightly while that of households declines a bit.

Figure 7: Final energy demand indicators

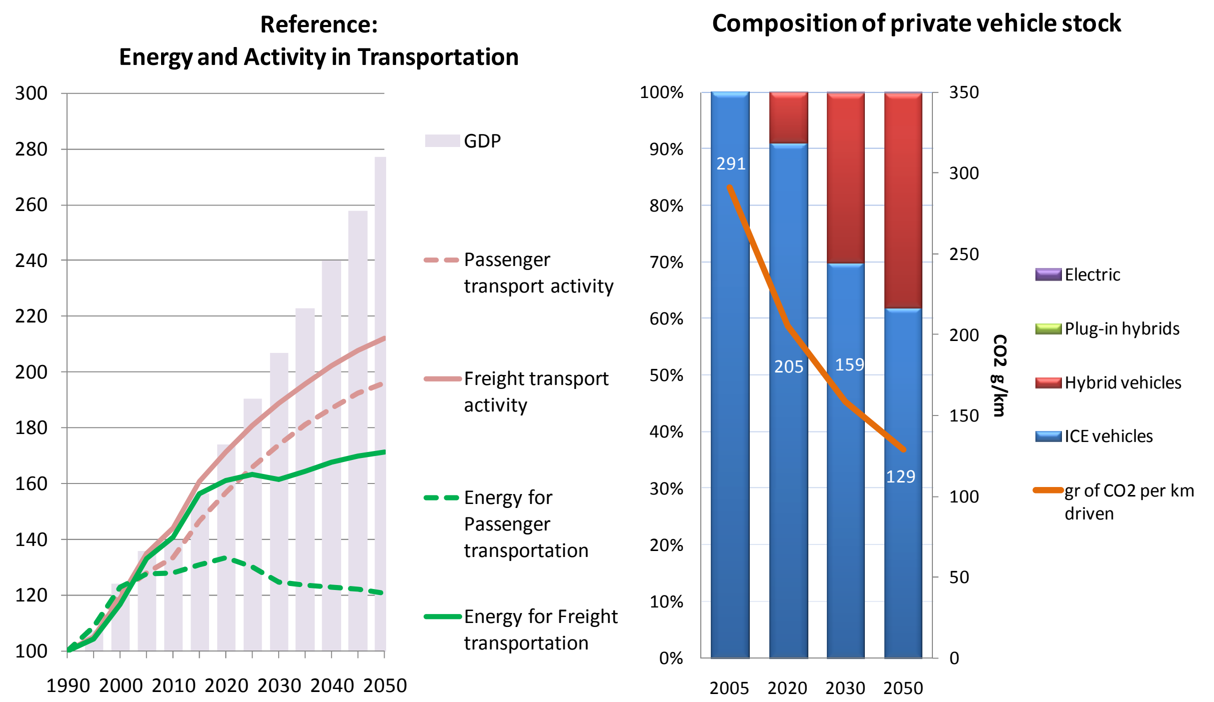


122 … and perhaps ever – except for much higher economic growth materialising (see below under sensitivities)

The energy intensity of different sectors decreases, as does the overall energy intensity of the economy. Increased energy efficiency in the residential sector is due to the use of more efficient energy equipment (appliances, lighting, etc.) and buildings as well as behavioural changes. The strong improvement in the energy efficiency of energy equipment is driven by the Eco-Design regulations and by better thermal integrity of buildings reflecting the Recast of the Energy Performance of Buildings Directive. While these improvements are sufficient to ensure a decrease in final energy demand over the projection period in the residential sector, the increased efficiency is not sufficient to compensate for higher needs in the tertiary sector.

In the transport sector, the correlation between GDP growth and transport activity is found to decouple somewhat when using satellite transport modelling tools. Energy consumption is decoupling much more significantly due to the use of more energy efficient vehicles, in particular hybrids. The CO2 from cars regulation is instrumental for this development. This scenario takes a conservative view regarding the development of alternative energy carriers such as electric and fuel cell cars; it does not assume strong policies leading to a shift towards electric mobility or plug-in hybrid vehicles in addition to the existing CO2 from cars regulation. The CO_2 emissions per kilometre driven decrease rapidly up to 2020 but as the regulation is not strengthened after 2020 in this scenario, improvements thereafter are due to stock renewal and some autonomous efficiency improvements brought about by markets as has been the case in the past. The penetration of biofuels in the Reference scenario is limited to road transportation; overall biofuels in liquid fuels achieve a share of 10% by 2050. The amount of RES in transport meets the 10% target in 2020 to comply with the RES directive and increases to 13.3% by 2050.

Figure 8: Energy and Activity in transport; composition of private vehicle stock[123]



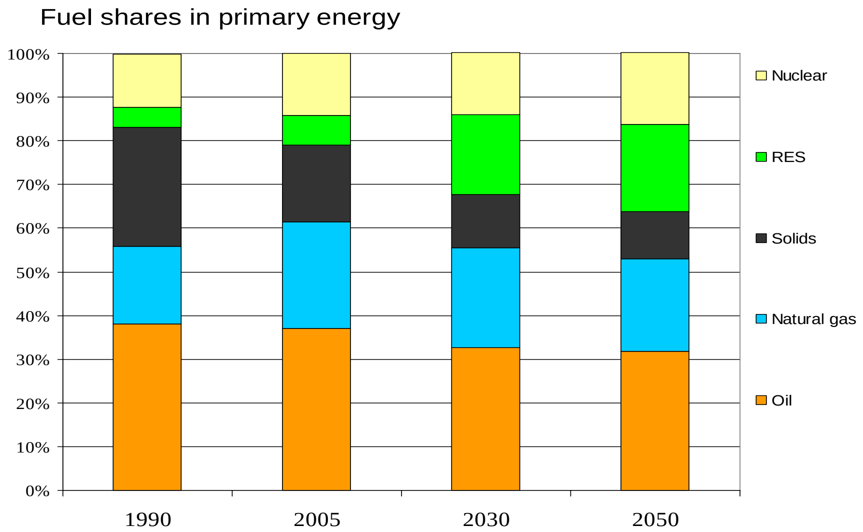
There is considerable fuel switching in final energy demand, especially in the residential and tertiary sectors where the use of fossil fuels (solids, petroleum products and gas) decreases

123 Freight transport does not include international maritime.

while there is a strong tendency towards electrification. The share of RES in final energy consumption increases markedly, reflecting the RES Directive. RES penetration continues with ongoing enabling policies (priority access, streamlined authorisation) whereas operation aid to mature RES technology is progressively reduced in this Reference case.

Also on the primary energy level, there is significant restructuring. This can be seen from the pronounced shifts in the shares of individual fuels up to 2050 (in terms of **primary energy**):

Figure 9: Fuel mix development



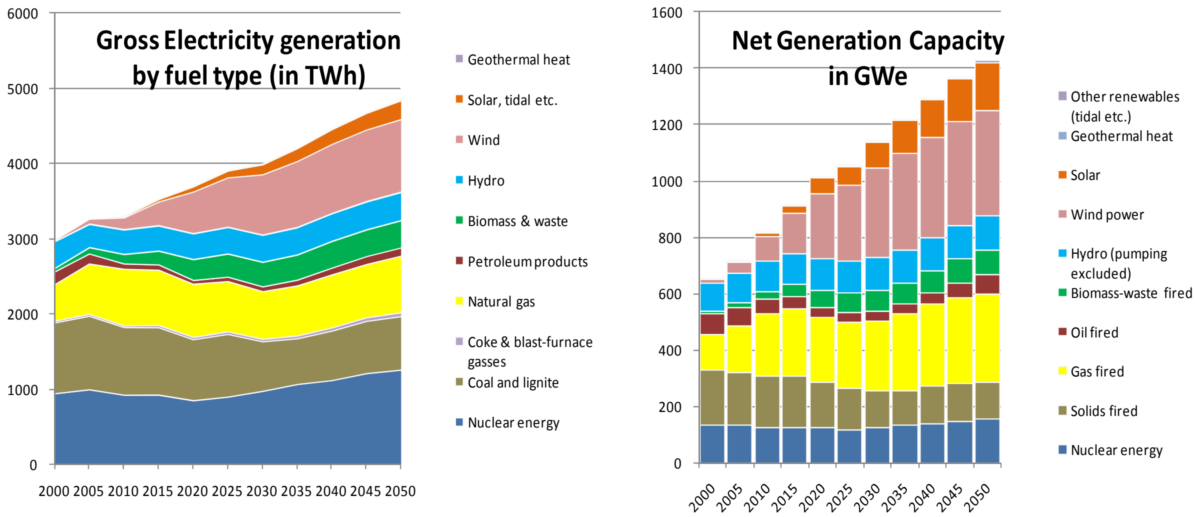
- RES gain 13 percentage points (pp) from 2005 (15 pp from 1990); making it the third most important primary energy source (after oil and gas) in 2050 (when it reaches 20% of primary energy consumption);
- Nuclear increases 2 pp from 2005 (4 pp from 1990), becoming more important than solid fuels (16% share in 2050);
- Oil loses 5 pp (6 pp on 1990); oil share in 2050 amounts to only 32%;
- Solids lose 7 pp from 2005 (16 pp from 1990) reaching just 11% by 2050;
- Gas declines least of all fossil fuels (-3 pp from 2005 to 2050); the gas share in 2050 is still higher than in 1990 (3 pp) because of the significant inroads made up to now; gas will represent more than a fifth of the primary EU energy mix in 2050 (21%);
- The dominance of fossil fuels diminishes with their share falling from 83% and 79% in 1990 and 2005, respectively to only 64% in 2050.

While non fossil fuels (RES and nuclear) account for 36% of primary energy in 2050, they reach a significantly higher share in the 2050 electricity mix. Energy sources not emitting CO2 supply 66% of electricity output, with 40% RES and 26% nuclear. In addition, 18% of electricity would come from CCS plants, which do however still emit some CO2.

Power generation changes substantially in the projection period; the demand for electricity continues rising and there is a considerable shift towards RES. As can be seen in Figure 10 installation of capacity and generation from wind increase steadily throughout the period. The incentives due to the RES target until 2020 are sufficient to make wind power generation competitive with other technologies. Power generation and capacity from solids decrease throughout the scenario due to the carbon prices that reduce the competitiveness of this technology; gas power generation capacity increases, also as peak load activated during back-up periods due to the increased amount of RES in the system. As a result of the large increase in RES in power generation the load factor of the system decreases due to the more widespread use of technologies that run only a limited number of hours per year, such as wind.

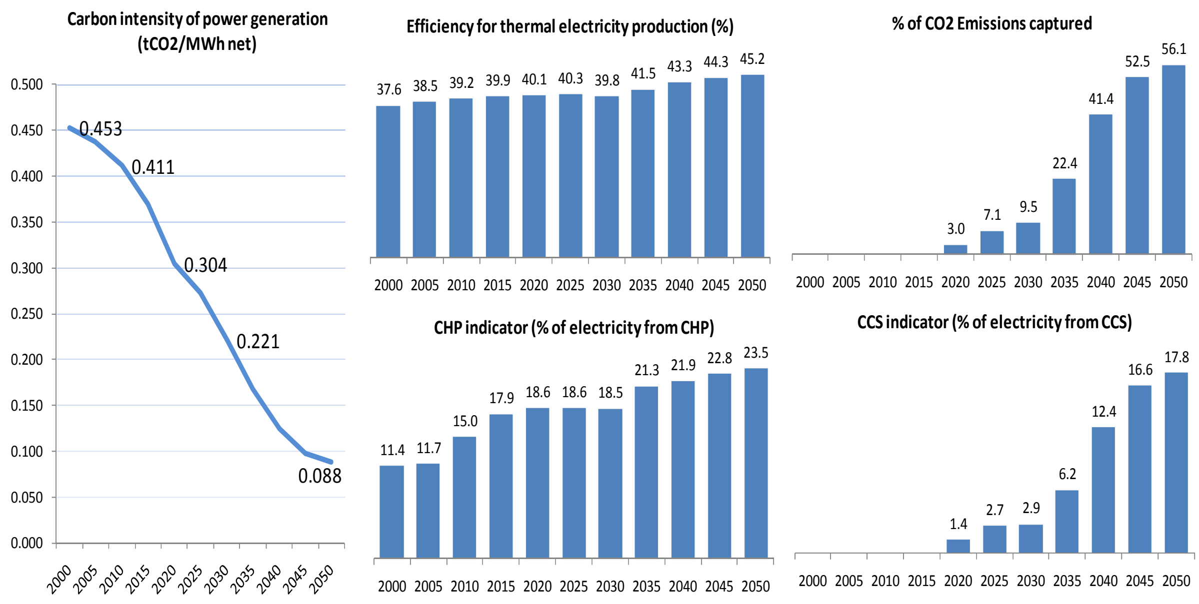
Investment in power generation increases over the projection period, driven by new investments in RES and gas.

Figure 10: Electricity generation and net generation capacity



The carbon intensity of power generation reduces by over 75% in 2050 compared to 2010 levels, driven by the decreasing ETS cap and the rising carbon prices (see Figure 11). In 2050 17.8% of electricity is generated through power plants equipped with CCS. This corresponds to a CCS share in fossil fuel power generation of over 50%. More than 50% of the potential emissions from the power generation sector are captured. The efficiency of thermal electricity production rises throughout the projection period due to the renewal of the power plants, in particular investment in gas and in spite of CCS being widely used in power generation. CHP plants are assumed to be integrated into the competitive electricity markets, facilitated by the CHP Directive and their share in electricity generation will rise. Incentives for CHP focus on electricity, which implies that an increase in electricity production from CHP power plants does not necessarily imply an increase in CHP capacity, given that there is some flexibility in the power to heat ratio.

Figure 11: Power generation indicators [124]

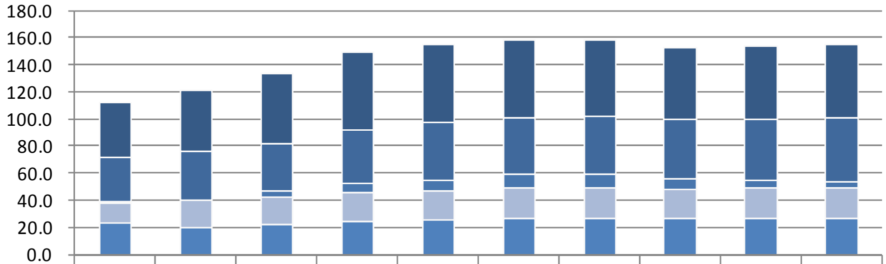


The price of electricity peaks in 2030 and decreases slightly thereafter. The price increase up to 2030 is due to three main elements: the policies inducing investment in RES, the ETS carbon price and the high fuel prices due to the world recovery after the economic crisis. Thereafter electricity prices do not increase further, indeed decline slightly, because of the technical improvements of technologies that limit the effects of higher input fuel prices. Moreover, taxes on fuels and ETS auction payments sink beyond 2030. This is due to the declining cap and the introduction of CCS in particular, which limits emission quantities and therefore auction revenues from the ETS despite rising ETS prices. Whereas the CO2 price increases, the average levy on electricity production, including the carbon free and decarbonised parts, declines in the long term. Moreover, there is a continued decrease in the use of diesel oil in power generation, which Member States may tax for environmental reasons.

[124] The percentage of emissions captured is calculated as the ratio between the total emissions captured and the potential emissions of thermal power plants, which are the remaining emissions plus the emissions captured.

Figure 12: Cost components of average electricity price

Cost components of electricity generation (Euro'10 per MWhe)



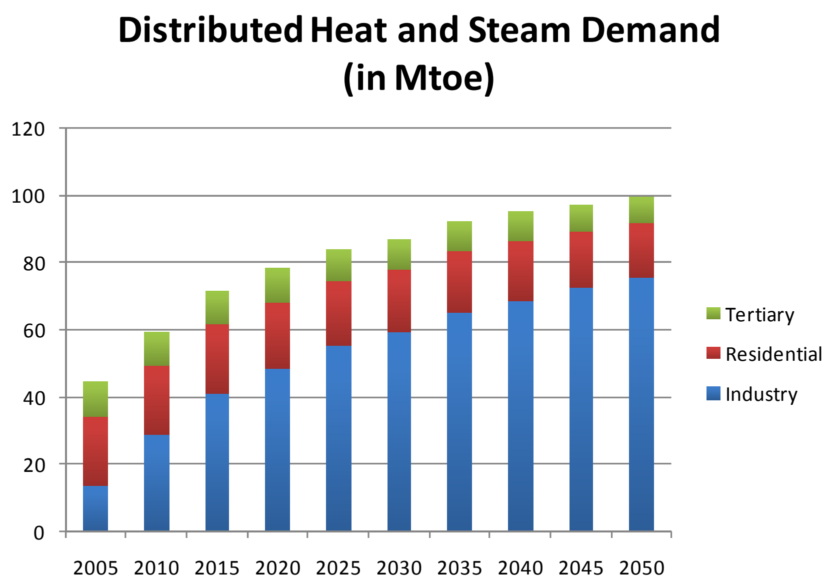
	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Fixed Costs	40.5	45.2	51.0	57.1	56.9	58.0	55.9	53.1	54.1	53.6
Variable and Fuel	32.7	35.8	34.7	39.6	42.9	41.6	43.2	44.2	45.3	47.2
Tax on fuels and ETS auction payments	1.0	0.6	5.4	6.3	7.6	10.2	9.9	7.4	5.7	5.1
Excise tax and VAT on electricity	14.2	19.3	20.1	21.2	21.7	22.1	22.2	22.0	22.1	22.2
Grid and sales costs	23.1	20.1	21.7	24.6	25.5	26.5	26.7	26.0	26.2	26.4
Average price of electricity (pre-tax)	97.3	101.6	112.8	127.7	132.8	136.2	135.7	130.8	131.4	132.4
Average price of electricity (after tax)	111.5	121.0	132.9	148.9	154.5	158.3	157.9	152.8	153.4	154.5

Distributed Heat

Demand for distributed heat demand rises in the Reference scenario throughout the projection period; a strong increase can be observed between 2005 and 2020 reflecting the strong CHP promoting policies in all Member States, as well as commercial opportunities that arise from gas based and biomass based CHP technologies. It is assumed that the same policies continue at least until 2020 as part of the implementation of the 20-20-20 policy package. Among the CHP promoting drivers worth mentioning are: the CHP directive (facilitating absorption of CHP-electricity by wholesale markets), national policies including feed-in tariffs and the ETS-carbon prices. CHP growth is limited by the geographic possibilities of the distribution system. District heating powered by boilers is a less attractive option, except in cases exploiting local resources e.g. biomass, and existing distribution networks.

In the longer term further demand for distributed heat in the tertiary and residential sectors seem to slow down as a result of the trend towards electrification (i.e. heat pumps) and higher energy efficiency which limits the overall demand for heating. In industry the increase in demand for distributed steam is projected to continue in the future because the changes of industrial activity are favourable for sectors with high demand for steam such as chemicals, food, drink, tobacco, engineering and other industries. Furthermore the development of the market for distributed steam and the possibilities of selling electricity to the wholesale market favours the construction of CHP units of different sizes and technologies in these industrial sectors

Figure 13: Heat demand by sector



Transport

Transport accounts today for over 30% of final energy consumption. In a context of growing demand for transport, final energy demand by transport is projected to increase by 5% by 2030 to represent 32% of total final energy consumption. This development is driven mainly by aviation and road freight transport. At the same time, however, the energy use of passenger cars would drop by 11% between 2005 and 2030 due to the implementation of the Regulation setting CO2 emission performance standards for new passenger cars[125]. After 2030 transport energy demand would increase only marginally up to 2050.

The EU transport system would remain extremely dependent on the use of fossil fuels. Oil products would still represent 88% of the EU transport sector needs in 2030 and in 2050 in the Reference scenario.

Energy Imports/ Security of Supply

Total energy imports increase 6% from 2005 to 2050. The increase is rather limited despite decreasing indigenous production, as rising gas and biomass imports are compensated by a marked decline in coal imports while oil imports remain broadly stable.

Gas imports continue to rise (28% from 2005 to 2050) due to declining production and despite decreasing consumption.

Import dependency rises only slightly above the present level (54%), reaching 58% in 2020 and flattening out to 2050 thanks to more RES and nuclear.

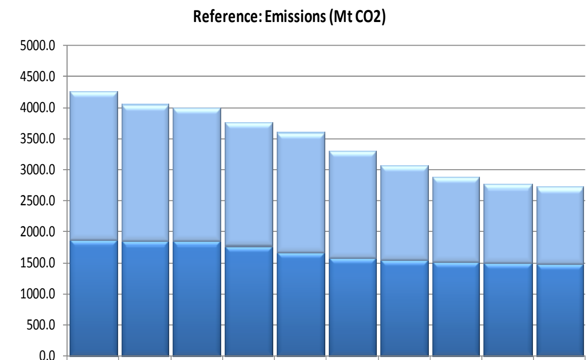
[125] Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles, OJ L 140, 5.6.2009, p. 1–15.

Emissions

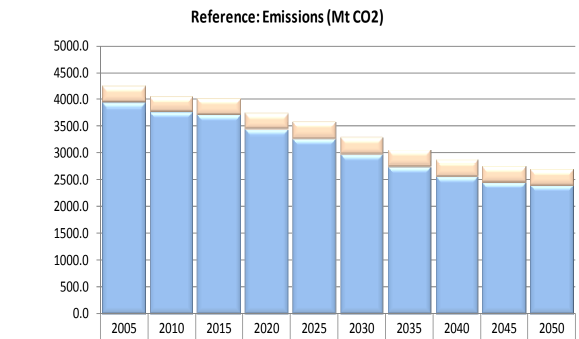
Energy related CO2 emissions decline much faster than energy consumption, giving rise to some decarbonisation of the energy system because of fuel switching to RES and nuclear at the expense of solid fuels and oil:

- Carbon intensity falls markedly. Producing one unit of GDP in 2050 would lead to only 30% of energy related CO2 emissions that were required per unit of GDP in 2005 and to just one fifth of what the CO2/GDP indicator was in 1990.
- Energy related CO2 emissions sink 40% below the 1990 level in 2050; thus the reference scenario represents about half of the efforts needed by a developed economy if a global deal to limit climate warming to 2°C will be achieved.
- CO2 emissions from electricity and heat generation fall almost 70% between 1990 and 2050 when they will make up 14 % of all GHG emissions (down from 27 % in both 1990 and 2005);
- Total GHG emissions decrease slightly less (39%) by 2050 from 1990. Whereas non-CO2 emissions fall somewhat more, the total emission decline is hampered by the very moderate decrease of CO2 from industrial processes (CO2 not related to fuel combustion).

Figure 14: CO2 emissions [126]



	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
ETS	2379.4	2198.4	2147.9	1982.1	1916.9	1716.9	1522.2	1358.5	1258.8	1226.8
Non-ETS	1871.6	1852.2	1860.4	1771.0	1675.3	1584.3	1548.0	1521.3	1506.1	1484.6
Total CO2	4251.0	4050.6	4008.3	3753.1	3592.2	3301.2	3070.2	2879.8	2764.8	2711.3



	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Process related CO2 Emissions	304.5	279.0	294.8	311.1	318.7	318.4	314.7	314.3	313.5	310.9
Energy related CO2 Emissions	3946.6	3771.6	3713.4	3442.0	3273.4	2982.8	2755.5	2565.5	2451.4	2400.4
Total CO2	4251.0	4050.6	4008.3	3753.1	3592.2	3301.2	3070.2	2879.8	2764.8	2711.3

The contribution to the emission reductions is driven by the ETS sectors which decrease emissions by 48% between 2005 and 2050; on the contrary the non-ETS sectors reduce by 21% compared to 2005. The share therefore shifts from 56% of emissions in ETS sectors in 2005 to 46% in 2050. Most emissions continue to be energy related emissions; energy related CO2 emissions decrease by 39% in the time period from 2005 to 2050 whereas non-energy related CO2 emissions increase by 3%.

Policy relevant indicators (and targets)

The indicative 20% energy savings objective for 2020 would not be achieved under current policies - not even by 2050. The reference case would deliver **10% less energy consumed in 2020 compared to the 2007 projections**.

[126] The split between ETS and non-ETS emissions reflects over the whole period the ETS scope as valid from 2013 onwards.

The reference case assumes that the RES target is reached in 2020; the RES share (as defined in the RES directive: as a percentage of gross final energy consumption) continues rising to reach 24% in 2030 and **25% in 2050**; further penetration of RES is limited due to the assumed phasing out of operational aid to mature RES technologies (see below). On the basis of final energy, the RES share gains nevertheless 17 pp between 2005 and 2050 (13 pp on the basis of primary energy).

The ETS carbon price rises from 40 € (08)/tCO2 in 2030 to 52 € in 2040 and flattens out to 50 € in 2050 (after having triggered some emission reducing restructuring in ETS sectors to comply with the dynamic requirements of the Directive).

These CO2 prices seem high enough to trigger significant CCS investment from 2040 onwards; whereas the CCS share in gross power generation reaches only 2% in 2030, it rises to 12% in 2040 and 18% in 2050 (this percentage is 15% in net power terms). CCS is mainly applied on solid fuel power generation, but also to gas power plants towards the end of the projection period; by 2050 half of solid fuel power capacities are equipped with CCS and 17% of gas power plants. Generation by solid fuel CCS plants represents 10% of net total power generation in 2050; the share of gas based CCS is 5% in 2050.

The reference case assumes the overall GHG target, ETS cap and non-ETS national targets to be achieved by 2020 but thereafter GHG reductions fall short of what is required to mitigate climate change with a view to reaching the 2 °C aim. While the reference case development lead to only 40% less GHG emissions from 1990, more than twice as much might be needed, i.e. minus 80-95% by developed economies.

2.2 Economic growth sensitivities

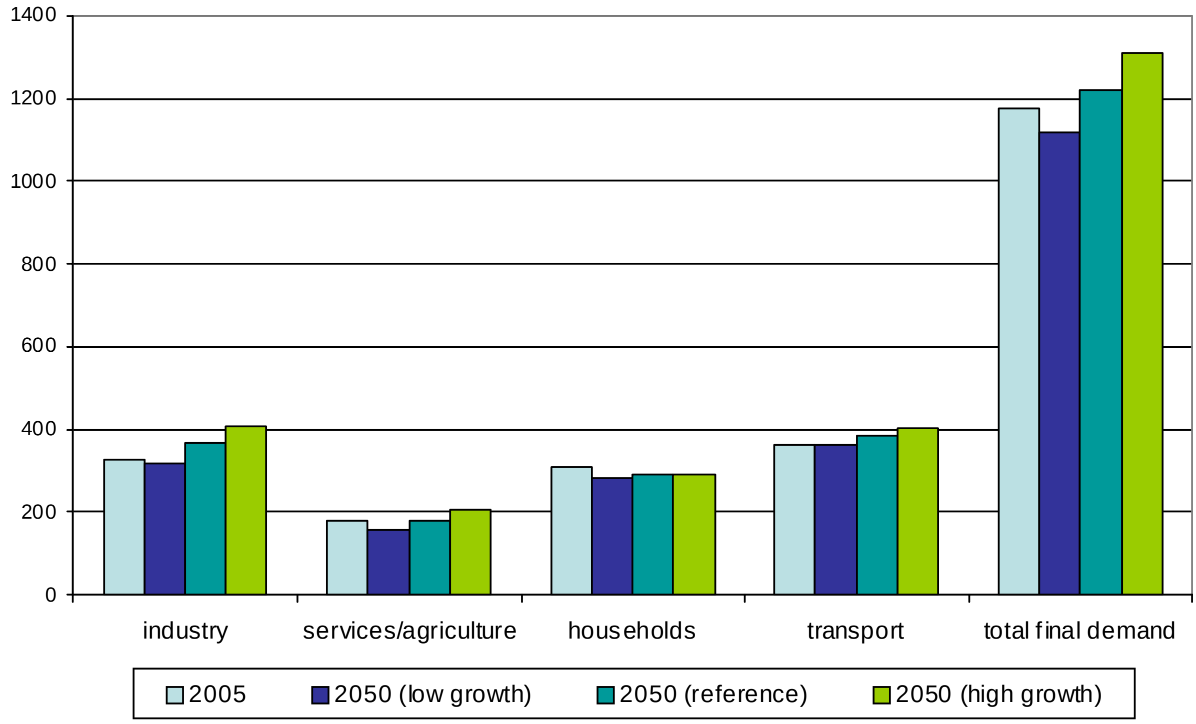
Economic activity is a key driver of energy consumption and therefore emissions. It can be expected that higher GDP growth rates will lead to higher energy consumption and CO2 emissions and vice versa in the case of lower economic growth.

Final energy demand

In fact, final energy consumption in the high economic growth case is 7.3% higher in 2050 than in the Reference case. This increase is however much lower than the increase in GDP (+15.0%) due to important energy intensity improvements. These improvements are linked in particular to the structure of the additional economic activity, which takes place mainly in less energy intensive sectors, such as market services and trade. Moreover, higher economic growth allows faster capital turnover so that more energy efficient equipment enters the capital stock sooner. Better capacity utilisation in case of high economic growth can also add to this improvement in energy intensity. Higher household income also allows for faster replacement with new, more energy efficient, appliances and cars, although the overall demand of energy services would increase via more purchase of higher performing items.

CO2 emissions from final energy demand rise slightly less than energy consumption thanks to some fuel switching to zero carbon (electricity and heat) or low carbon fuels (gas). In 2050, CO2 emissions in final demand are 6.9% higher than in the Reference case (while energy demand and GDP are 7.3% and 15% higher, respectively).

Figure 15: Final energy consumption broken down by sector in different economic growth cases (in Mtoe)



Additional energy consumption is most pronounced in the services/agriculture sector where demand in 2050 is 14.9% higher than in the Reference case. Again, CO2 emissions rise less than energy consumption thanks to fuel switching connected especially with more use of electricity[127]. In 2050, CO2 emissions from this sector exceed the Reference level by 12.6%, falling nevertheless well below current levels (see table 6).

With less pronounced expansion of economic activities in industry there is lower, but still considerable, growth in final energy demand. Increased industrial activities require more energy inputs so that industrial energy demand exceeds Reference case levels in 2050 by 9.9%. Energy consumption growth in industry is fossil fuel intensive with higher demand for carbon rich coal in certain branches, which – under constant CO2 policies via the EU ETS - leads to higher CO2 emissions, which exceed the Reference case level in 2050 by 12.0%. It is however worth noting that even with such high economic growth, industrial CO2 emissions in 2050 remain below today's level.

Table 6: CO2 emissions from final energy demand sectors in different economic growth cases (in Million tonne CO2)

	1990	2005	2050 low growth	2050 Reference	2050 high growth
Industry	781	582	361	425	476
Services/agriculture	301	262	136	158	178
Households	499	487	292	297	303
Transport	813	1053	951	1007	1061
Total final demand	2394	2384	1740	1888	2018

Energy consumption of households rises much less in comparison to the Reference case (by 1.9% in 2050) because many energy services, such as heating and cooking are very income inelastic once certain comfort levels have been reached. Moreover, increased purchases of appliances in the context of higher incomes concern items with lower specific energy consumption compared with the existing stock, a process that is being made more pronounced with eco-design Regulations. Household CO2 emissions in 2050 are just 2% higher than in the Reference case, but still a third lower than today.

Transport energy demand exceeds Reference case levels by only 5.5% in 2050. The reason is similar to that for households. Except for holiday trips, passenger transport activity tends to grow slower than private incomes. On the contrary, freight transport activity is much more influenced by the level of economic activity. In the absence of major possibilities for fuel switching under current trends and policies, higher transport energy demand translates directly into higher CO2 emission (5.3% higher than Reference in 2050), keeping emissions at current levels in 2050.

[127] However, it should be noted that such higher electricity demand could lead to higher CO2 emissions, depending on the fuel input structure, which are accounted for under power generation (see below)

The improvement of carbon intensity in final energy demand under high economic growth (lower CO_2 growth than growth of final energy demand) is mainly due to fuel switching towards electricity, which has been an ongoing trend with higher incomes and structural change in the economy (e.g. more ICT based services). Higher economic growth would lead to 8.8% higher electricity consumption (compared with Reference) in 2050 with CO_2 consequences for power generation.

Higher GDP growth leads to higher demand for heat (+ 7% in 2050) in line with overall increase of final energy demand but significantly lower than increase in GDP (+15%). The growth comes mainly from industry and tertiary sectors reflecting higher economic activity in these two sectors. Residential demand is rather stable (+1%) as heat is an essential need and not very elastic to changes in household income. Supply increases from both CHP and district heating units.

Lower economic growth entails lower energy consumption and emissions in all sectors. With GDP in 2050 remaining 14.7% below the Reference case level, there would be a reduction of final energy demand by only 8.4%. Consequently, energy intensity (of final demand) would deteriorate compared with the Reference case (and even more so in the high growth case). Slower capital turnover in case of sluggish economic growth is one reason for this as well as a lot of energy uses being rather income inelastic, such as home heating and cooking. CO_2 emission would decline to a somewhat smaller extent than energy consumption (only by 7.8% in 2050 compared with Reference). Low carbon content fuels reduce somewhat more than the more carbon intensive ones, leading also to a slight worsening of carbon intensity of final energy demand.

Energy demand in services/agriculture would fall almost as much as GDP in 2050 compared with the Reference case (-14.3%). The decline in CO_2 emissions would be similar (-13.8%). Industrial energy consumption and emission decrease also markedly with lower economic growth; they are down on the Reference case in 2050 by 13.6% and 15.1%, respectively. CO_2 emissions reduce somewhat more than energy consumption, as fossil fuel demand drops slightly more than demand for electricity and steam that are carbon free at use.

By comparison, households and transport reaction to lower GDP is much less pronounced. Household energy consumption and CO_2 emissions are both down 2% on the Reference case 2050 level (i.e. substantially less than the decline in GDP: almost -15%). Given that freight transport reacts rather strongly to lower economic activity while passenger transport decreases comparatively little with lower income, transport energy consumption falls 5.7% below the 2050 reference case. CO_2 emissions sink by almost the same percentage (-5.5%), as possibilities for fuel switching are limited in a Reference case environment without intensified climate or renewables policies.

Lower economic growth leads to a rather strong reduction of electricity demand, which remains 9.7% below the Reference case level in 2050, still exhibiting healthy growth from current levels.

Demand for distributed heat decreases by 10% in 2050 compared to the Reference scenario mainly due to sharp decreases in tertiary (-14%) and industry (-12%) sectors reflecting lower economic activity. Residential demand reacts much less (-3%) as heat is an essential need and not very elastic to changes in household income. There is a shift from CHP production (-11% in 2050 following lower electricity demand) to higher district heating units production (+10%).

Electricity generation

Electricity demand is particularly sensitive to variations in economic activity. With limited possibilities for electricity imports this translates into a similar requirement on the generation of electricity in the EU. In the high economic growth case with 15% higher GDP in 2050, gross electricity generation exceeds the 2050 reference case level by 9.2%. Similarly, 14.7% lower economic activity in 2050 entails 10.2% less electricity generation in 2050.

Whereas the level of electricity generation strongly depends on the magnitude of economic growth, its structure changes much less with lower or higher GDP in 2030 and 2050. In 2030, the RES share in electricity varies within a margin of 1 percentage point around 40.5% in the Reference case (see table 7 on fuel shares in generation). This range becomes somewhat larger in 2050 (around 2 percentage points). With unchanged support for RES, higher economic growth encourages in particular nuclear and fossil fuel generation, leading to a somewhat lower RES share in power generation; it should be noted that the absolute level of RES based electricity generation is significantly higher with high economic growth (+5.3% in 2050 compared with Reference).

Table 7: Electricity related indicators under different economic growth assumptions

	High economic growth		Low economic growth		Reference case	
	2030	2050	2030	2050	2030	2050
Gross electricity generation (TWh)	4229	5386	3848	4422	4067	4931
Shares in gross electricity generation						
RES share	39,8%	38,8%	41,5%	42,5%	40,5%	40,3%
Nuclear share	25,1%	27,4%	23,2%	25,3%	24,5%	26,4%
Fossil fuel share	35,1%	33,8%	35,3%	32,2%	35,0%	33,3%
CCS share	4,2%	20,3%	1,6%	12,1%	2,9%	17,8%
Prices in €						
ETS (€(08)/t CO2)	50,0	52,5	32,0	41,5	40,0	50,0
Average electricity price (in €(08)/MWh)	159,7	153,9	157,0	153,5	157,7	153,8

High economic growth brings about higher ETS prices (see table 7), which in turn encourage CCS deployment. Combined with a higher share of fossil fuel based power generation, this leads to CCS shares in power generation that are higher than Reference in 2030. The increase is particularly pronounced in 2050, when 20% of total power generation would be equipped with CCS. On the contrary, with low economic growth leading to low ETS prices as well as lower fossil shares in power generation, CCS amounts to only 12% in 2050.

Electricity prices are rather insensitive with respect to variations in economic growth. Higher economic growth increases the 2030 average electricity price slightly by 1.2%, while lower economic growth would lead to an electricity price that is 0.4% below the Reference case price. These electricity price modifications relate to the significant changes in ETS prices brought about by variations in allowances demand due to growth of energy demand and changing fossil fuel inputs to power. In 2050, when the variation in ETS prices from the Reference case is pretty small, the variations in electricity prices become marginal or even undetectable (electricity prices: minus 0.2% with low GDP growth and 0.0% with high growth). Consequently, different economic growth patterns do not alter the Reference case result that shows strongly rising electricity prices up to 2030 in the context of higher fixed costs following the restructuring of the power generation system for reaching the RES and GHG targets, with a stabilisation of prices in the following two decades.

Primary energy consumption and energy intensity

As was discussed in the part on final energy demand, certain parts of energy consumption react only to a limited extent to variations in economic growth; this concerns in particular the household sector and also passenger transport. Combined with more favourable conditions for improving energy efficiency under high economic growth (bringing about, together with structural change in economic activity, 5.8% better energy intensity), this leads to primary energy demand rising much less than GDP. Compared with the Reference case, primary energy demand increases 3.4% in 2030 while GDP is 6.3% higher, in 2050 primary energy exceeds the Reference case by 8.4% with the economy being 15.0% larger in terms of GDP.

Also in the case of lower economic growth, the effects on primary energy consumption are moderated by the less income elastic consumption sectors (households, where heating needs remain largely the same, as well as passenger transport having rather unchanged needs for commuting, shopping and similar travelling). Moreover, lower capital turnover with lower economic growth limits the opportunities for investing in energy efficient items. As a result, energy intensity worsens by 6.4% in 2050. Consequently, energy consumption sinks significantly less than GDP. With 7.7% lower GDP in 2030 compared with the Reference case, primary energy is down 5.0%; in 2050 with 14.7% lower GDP compared with Reference there is a decline of primary energy by just 9.3%.

These energy intensity effects (the improvement of 5.8% compared with Reference in 2050 under high economic growth and the 6.4% deterioration under sluggish GDP growth) limit the impacts of alternative developments of GDP on CO2 emissions. Another countervailing (or reinforcing) factor could come from changes in the fuel mix. Different economic growth patterns exert somewhat different influences on individual fuels.

Fuel mix and carbon intensity

Under high economic growth, oil and gas consumption grow less than overall energy consumption. Nuclear reacts in a more pronounced way (above average) given its exclusive use in power generation, which in turn is more sensitive to variations of GDP. Also the reaction, to higher economic growth, of solids being mostly used in power generation is fairly marked in 2050, given the absence of strong CO2 limitation policies. On the assumption of unchanged RES support schemes, RES are not particularly encouraged by higher economic growth.

On the other hand, RES are not particularly discouraged by lower economic growth. The negative effects of such GDP losses on nuclear and solids are much stronger, exceeding the percentage changes of total energy consumption. Oil and gas sink largely in line with the reduction in total energy demand.

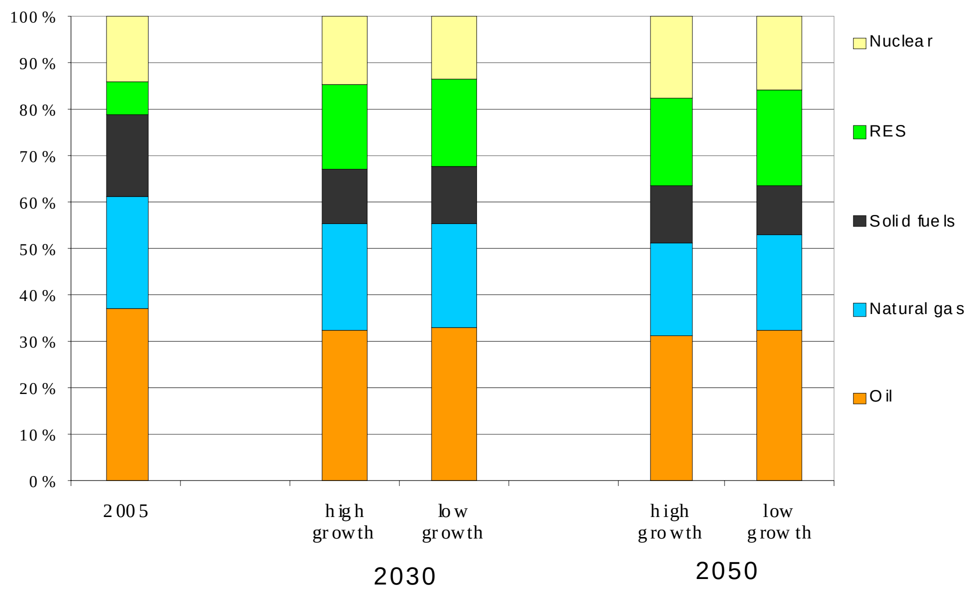
This leads to the following fuel shares in 2050:

- Oil reaches shares between 31% and 32.5% under high and low economic growth, respectively;
- The gas share amounts to 20% in both growth cases;
- Solids account for 12% under high and 10.5% under low economic growth;
- The nuclear share reaches 17.5% under high and 16% under low economic growth
- RES increase their share to 19.5% with high GDP and even 21% with lower economic expansion;

When evaluated in terms of gross final energy consumption (definition in the RES Directive), the RES shares amount to 25% under high and to 26% under low economic growth, which represents increases from the 2005 level of between 16 and 18 pp in the high and low GDP case, respectively. The RES share in transport is also pretty robust across economic growth cases amounting to 13% in 2050 under the different GDP assumptions, up half a percentage point from its level in 2030.

While there are only limited changes of fuel shares across economic growth cases, the evolution of fuel shares over time, especially regarding RES, is pretty dynamic. Fossil fuels in total lose around 16 percentage points between 2005 and 2050, with somewhat higher losses for solids and oil. RES gain between 12.5 and 14 percentage points under high and low growth, respectively, while nuclear accounts for the remaining gain.

Figure 16: Development of the fuel mix under high and low economic growth



The overall result of these changes in the fuel mix is that the carbon intensity improves with higher economic growth, i.e. one unit of energy consumed results in slightly less CO2 emissions under high growth (1.32 t CO2/toe in 2050) than in the Reference case (1.36 t CO2/toe for the same year). The opposite effect on carbon intensity comes about under lower economic growth, in which case one tonne of oil equivalent energy consumption is associated with CO_2 emissions of 1.45 tonnes, which equates to a 6.4% worsening.

Total CO2 emissions

These effects on energy and carbon intensity and the existence of the ETS with a given emission cap mean that GDP-induced changes in CO2 emissions are much less significant than underlying changes in GDP. With 15% higher GDP in 2050, CO2 emissions are only 5.3% higher (both on Reference in 2050). Similarly, a GDP drop of 14.7% leads to CO2 emissions that are only 3.3% lower in 2050. For 2030, a GDP rise on Reference by 6.3% is associated with a 1.2% increase of CO2 emissions, while a GDP loss of 7.7% entails 2.3% lower CO2 emissions (compared with Reference case).

It can be concluded that emission results are pretty robust with respect to variations of GDP. This reduces greatly one possible uncertainty regarding policy objectives on emissions, as there are mechanisms (ETS, effects on energy intensity) that limit the effects of variations in GDP levels on energy consumption and on CO2 emissions. This is important given the great uncertainty in projecting economic activity for the coming years, let alone over the next four decades.

While there are such energy and carbon intensity effects, limiting the impact of economic activity on CO2 emissions, alternative economic developments would still alter the expected decline in CO2 emissions up to 2050. Such a decline of emissions materialises under Reference case policies and is also brought about by Current Policy Initiatives and even more so in decarbonisation scenarios.

Emissions reduce somewhat more over time with lower economic growth and somewhat less with higher economic growth. Variations in CO2 reductions from 1990 levels are however marginal in 2030 (around 1 percentage point more or less CO2 reduction from Reference case level in 2030 with higher or lower growth), while GDP varies 6-8 percentage points. In 2050 variations in the policy relevant indicator: CO2 reductions from 1990 around what would materialise in the reference case are still rather small (plus/minus 2-3 percentage points) - with GDP varying 15 percentage points around the reference case level.

Table 8: CO2 reduction below 1990 (index 1990 =100) and major drivers

1990 = 100	2030			2050		
	High growth	Reference	Low growth	High growth	Reference	Low growth
GDP	220	207	191	319	277	236
Energy consumption	108	104	99	115	106	96
CO2 emissions	75	74	72	63	60	58

Again, the possibilities for technically achieving GHG gas targets are not overly dependent on the level of economic growth. In any case, it needs to be borne in mind that GHG reduction requires innovation and investment, which is harder to finance in a low economic growth environment. Overall, emission reduction may be rather facilitated with sustained economic growth.

Finally, regarding the GHG emission reductions in ETS and non-ETS sectors, there is as to be expected with a given emission cap particularly little variation across economic growth cases for ETS sectors, whereas the GDP growth cases are somewhat more contrasted regarding non-ETS emissions.

Non-ETS GHG emissions reduce comparatively little up to 2030 under high economic growth and stay almost flat thereafter, whereas there is still a slight decrease in the reference case. Nevertheless, these changes are much lower than the underlying changes in GDP. In case of sluggish economic development, non-ETS emissions would continue declining through 2050. However, the reduction from Reference in 2050 is much lower than the decline of GDP.

Energy imports and external dependency

Total net energy imports increase 16% from 2005 to 2050 under high economic growth, whereas they decline 4% with low GDP (Reference case: 7% increase). Increasing imports of both gas and biomass contribute to the import rise in both economic growth cases, whereas imports of solid fuels decline both under high and low GDP assumptions; oil imports increase with higher economic growth and decline under low economic growth.

Despite different developments of energy imports in quantitative terms, import dependency as a percentage of total supply stays constant at 58% in 2050 in the different economic growth cases, marginally up from 57% in all cases in 2030 and an estimated 54% in 2010.

Conclusions on economic growth variants

The model based analysis shows that policy relevant indicators are pretty robust against variations in economic growth assumption, which is a significant result, given the great uncertainty in making GDP projections for the next few years let alone the next four decades.

- CO2 reduction becomes only slightly more difficult in technical terms under significantly higher economic growth. Moreover, it is important to note in this context that higher economic growth brings also more opportunities for innovation and investment in low carbon technologies, thus facilitating climate change mitigation and dealing with the competitiveness and energy security aspects. This result stems from improvements in both energy and carbon intensity facilitated by the ETS emission cap in place.

- In a similar manner, the countervailing effects through energy and carbon intensity are also present in the case of low economic growth so that there is only limited further emission reduction brought about by considerably lower GDP levels.

- RES shares are pretty robust with respect to GDP levels with variation spanning just 1 percentage point in 2050 for the RES share in gross final energy demand (overall indicator of the RES Directive). Similar results hold for the RES share transport and to a slightly lesser extent for the RES-E share.

- High economic growth gives rise to more energy intensity improvements, but would render absolute energy saving objectives with respect to e.g. a statistical year more difficult to achieve (with opposite conclusions under low economic growth). Energy saving objectives, such as the current one for 2020, are measured in absolute terms (without reference to GDP). However, energy consumption reacts to economic growth; it rises with higher GDP and declines in the opposite case.

- Policy relevant indicators regarding competitiveness are pretty much unaffected by economic growth; while ETS prices differ to some extent the effects on electricity prices are marginal.

- Exposure to external dependency measured as share of energy imports in energy supplies is also unaffected by such significant changes in GDP levels.

2.3 Energy import price sensitivities

Two such sensitivities were modelled spanning a fairly wide range around the Reference case price trajectories (see assumptions part above for details). The world oil price in 2050 is assumed to be 28% higher than the Reference scenario in the high price case, whereas it stays 34% below Reference in the low price case. In the low price case, fossil fuel import prices remain broadly at the 2010 level; coal prices are stable, oil has a small peak around 2030, whereas gas prices remain weak over the next few years but recover to the 2010 level in the long run.

Higher import prices bring about higher end-user prices discouraging energy use in the various sectors and vice versa. Moreover, such developments change the competitive position of individual fuels and technologies given all the other cost elements in addition to fuel input costs in the formation of end-user prices (e.g. capital costs and taxes). Effects are therefore differentiated according to fuel and sector. For example, electricity prices are less affected than end user prices of e.g. gas. Similarly, the percentage increase of end user prices following higher import prices is much more pronounced in e.g. industry compared with transport where existing high excise taxes moderate the increase in percentage terms.

Energy consumption

Under **higher energy import prices** (oil price up 28% on Reference in 2050), final energy consumption decreases by just 2.3% in 2050 from the Reference case. The decline spans from 1.1% in transport to 4.7% in services/agriculture where more electricity use, encouraged by higher prices of competing fuels, improves the energy intensity of the sector (electricity at use having a very high efficiency). Total electricity use in final energy consumption rises 1.0% compared with Reference in 2050.

Primary energy demand decreases 2.0% in 2050 compared with Reference, mirroring also the price induced effects in the energy transformation sectors notably in power generation as well as price inelastic parts, such as energy use as feedstock in the petrochemical industry.

Whereas higher energy prices exert only a limited effect on the level of energy consumption, the influence on the fuel mix is important. Gas demand reacts most strongly to rising prices given its use as a major input fuel for power generation where it competes with coal, RES and nuclear, which are either not affected (RES, nuclear) or less affected by rising fossil fuel import prices (see assumption part above). Gas demand in 2050 would fall by 14.7% in 2050 compared with Reference. Oil demand would also decline by 3.3% in 2050. The limited reaction is due to the concentration of oil use on petrochemicals and transport, where price reactions are small due to lack of substitutes and high existing tax levels in transport.

The use of solid fuels is encouraged despite higher import prices as gas competitiveness suffers in particular as a result of the more pronounced price increases (this is also linked to the cost structure in power generation where fuel costs are relatively more important for gas given its lower capital costs than for coal plants). Solid fuel use would increase 2.2% over Reference in 2050. Nuclear benefits also from higher fossil fuel import prices gaining 4.4% on Reference in 2050. Renewables win most, reaching 5.4% higher use compared with Reference in 2050.

In the case of **low energy import prices** (-34% in 2050 from Reference), final energy demand would increase by only 4.2% above Reference in 2050. The increase would be particularly high in services/agriculture where higher gas and oil use would be encouraged to the detriment of electricity. As electricity loses competitiveness, it contributes less to overall energy intensity improvements. Similar effects occur in households, while demand rises in the other sectors stay well below average. Electricity demand under low prices sinks 2.2% in 2050 compared with Reference.

Lower fossil fuel energy import prices entail 5% decrease in heat and steam demand, mainly due to decrease in industry (-9%). There is also a shift from CHP generation that looses 5% in 2050 to district heating units (+14%).

Primary energy consumption increases 2.8% in 2050 compared with Reference. The lower increase than for final energy is linked to lower electricity demand, which entail somewhat lower electricity generation and therefore transformation losses.

Again, with limited effects on overall energy consumption there are considerable changes in the fuels mix. Gas consumption increases 23.0% over Reference in 2050, while oil demand rises 4.8%. Solids, RES and nuclear, having all power generation as major areas of use, are discouraged, also because their prices do not fall (RES, nuclear) or to a lesser extent (solids). Solids use drops 7.3% below Reference, nuclear declines by 7.6%, while RES reduce least below Reference in 2050 (-6.6%).

Fuel mix

Consequently, the fuel mix would be somewhat altered both in the high and in the low energy import price cases.

Table 9: Shares of energy sources in primary energy consumption (in %)

	2005	2030			2050		
		High price	Ref.	Low price	High price	Ref.	Low price
Oil	37.1	32.0	32.8	32.4	31.3	31.8	32.4
Gas	24.4	20.3	22.2	25.4	17.7	20.4	24.4
Solids	17.5	13.0	12.4	11.7	11.8	11.4	10.2
Nuclear	14.1	15.4	14.3	13.2	17.8	16.7	15.0
RES	6.8	19.5	18.4	17.5	21.4	19.9	18.1

The marked variations in the import prices give rise to rather limited changes in the fuel share trends. Fossil fuels, especially solids, lose importance under both high and low prices, while RES make substantial inroads und nuclear progresses in the long term under high prices.

Variations across scenarios regarding the fuel shares are most important for gas, for which high import prices could lead to a considerable decline in its contribution (falling to only 17.7% in 2050 whereas low import prices could help maintain its current share in 2050 and even increase it somewhat in 2030 to over a quarter).

Power generation

Fossil fuel import prices render direct use of fuels more expensive. They result in lower percentage price increases for electricity given the rather small part of fuel input costs in total electricity costs. Under high fossil fuel prices, electricity production is encouraged, whereas it falls below Reference case under low import prices.

RES and nuclear benefit from high fossil fuel import prices. Low fossil fuel prices affect in particular nuclear penetration. The RES share remains stable due to rather unchanged production still benefiting from RES support and sinking overall electricity generation (compared with Reference). The fossil fuel share in power generation would go down to only 30% in 2050 under high energy import prices, down from 55% in 2005.

CCS penetration would be somewhat encouraged by lower fossil fuel prices and corresponding higher ETS carbon prices to ensure meeting the emission cap, leading to almost 4 percentage points more deployment in 2050. On the contrary high fossil fuel prices would delay its introduction so that the CCS share would be about 3.5 percentage points lower in 2050 compared with Reference.

Table 10: Electricity related indicators in different energy import price cases

	High import prices		Low import prices		Reference case	
	2030	2050	2030	2050	2030	2050
Gross electricity generation (TWh)	4103	4952	4003	4841	4067	4931
Shares in gross electricity generation						
RES share	40,6%	42,1%	40,6%	40,6%	40,5%	40,3%
Nuclear share	25,4%	27,4%	23,4%	24,9%	24,5%	26,4%
Fossil fuel share	34,0%	30,4%	36,0%	34,5%	35,0%	33,3%
CCS share	1,5%	14,4%	3,1%	21,5%	2,9%	17,8%
Prices in €						
ETS (€(08)/t CO2)	37,1	46,2	41,0	52,5	40,0	50,0
Average electricity price (in €(08)/MWh)	165,1	159,5	149,8	140,8	157,7	153,8

Electricity prices are lower than Reference with low import and therefore power generation input prices, while the opposite is the case with high import prices. The time profile of prices remains the same as under Reference case developments (see above).

CO2 emissions

The changes in the fuel mix and CCS penetration have important effects on CO2 emissions and ETS prices. With significantly more zero carbon power generation under high fossil fuel prices, ETS prices in the high import price case are somewhat below Reference, despite lower CCS penetration and somewhat higher electricity generation, given that with a constant ETS cap there is less demand for allowances. Under low import prices the opposite trends materialise and ETS prices are higher. In total, significant changes in the level of world energy prices exert only a small influence on ETS prices, as long as the coal to gas price ratio does not change significantly.

In the high fossil fuel price case, larger use of zero carbon fuels, moderated by effects on coal and lignite consumption as well as lower CCS deployment and slightly lower ETS prices bring about a marginal improvement in carbon intensity of primary energy consumption (1.35 t CO2/toe instead of 1.36 t CO2/toe in 2050 in Reference). Combined with the 2.0% improvement of energy intensity under high import prices, this leads to a 2.7% reduction of CO2 emissions below Reference in 2050.

In the low fossil fuel price case, in which oil and gas prices remain virtually flat at 2010 level through 2050 rather than increasing as in the Reference case, there is a more marked increase of CO2 emissions from Reference in 2050 (6.6%), in particular due to increases of non-ETS emissions with lower fuel prices. This is due to energy intensity deteriorating 2.8% compared with Reference in 2050 combined with a worsening of carbon intensity by 3.7%. Carbon intensity rises to 1.45 t CO2/toe in 2050 as a result of delayed CCS and higher shares of gas and of oil in the long run.

It can therefore be concluded that important further rises in oil and gas import prices, under a given emission cap for power and energy intensive industries, lead to only minor changes in CO2 emissions via limited effects on energy intensity and marginal effects through changes in fuel mix and technology deployment. The CO2 effects of lower fossil fuel prices (virtual stabilisation of fossil fuel import prices) appear to be proportionately more pronounced in the long term than those from further price increases above Reference case levels.

Table 11: CO2 reduction below 1990 (index 1990 =100) and major drivers

1990 = 100	2030			2050		
	High prices	Reference	Low prices	High prices	Reference	Low prices
Oil ($(08) / barrel)	149	106	91	162	127	84
Energy consumption	102	104	105	104	106	109
CO2 emissions	71.7	74.0	76.1	57.9	59.6	63.5

Higher world energy prices bring lower CO2 emissions including in the sectors subject to ETS, which in turn reduces both demand for allowances and their price, given the fixed cap. Conversely, lower fossil fuel prices increase emissions and therefore demand for allowances, leading to higher ETS prices.

In total, differences in world energy prices exert only a minor influence on total CO2 emissions in the EU. There are feedback mechanisms via ETS carbon prices. High fossil fuel prices reduce demand and CO2 emissions and thereby carbon prices. With low fossil fuel prices there is upward pressure on CO2 emissions and carbon prices increase under ETS.

Energy imports

Net energy imports fall 6.9% below Reference in 2050 under high import prices. Gas imports are particularly sensitive to variations in price levels (-15.7% on Reference in 2050) given the competitive environment in power generation and most final demand sectors, where ample substitution possibilities exist. Oil use is less flexible (transport, petrochemicals) so that oil imports decline by only 3.4% in 2050. Solid fuel imports are even less affected (-2.0%), while imports of biomass increase (4.9%) given higher demand.

Low energy prices encourage significantly higher net energy imports, which in 2050 exceed the Reference level by 11.0%. Gas is the main driver for this increase, with imports being 25.2% higher than Reference in 2050. Again, oil and coal imports react more moderately, rising 5.0% and 6.5%, respectively. With lower RES consumption, biomass imports would fall 11.5% below Reference in 2050.

Import dependency in the high price case would stay at the current level throughout the projection period reaching 54% in 2030 and 55%. Under low energy prices import dependency would increase slightly reaching 58% in 2030 and 62% in 2050 (up over 4 percentage points from Reference).

Energy costs

Higher and lower fossil fuel import prices impact strongly on the EU's external energy bill. With fossil fuel prices exceeding significantly the Reference level (e.g. oil by 41% and 28% in 2030 and 2050, respectively), the EU has additional costs over Reference for fossil fuel imports of 158 bn € (08) in 2030 and of 148 bn € (08) in 2050. The average annual extra fuel bill over the next 40 years amounts to 131 bn (08); it is worth noting that this is per year and in real terms.

In the low fossil fuel import price sensitivity, i.e. in case energy import prices remain essentially at the 2010 level, there are considerable external fuel bill savings. The costs for importing oil, gas and coal would decrease by 88 bn € (08) in 2030 and by 230 bn € (08) in 2050 with respect to Reference developments, in which fossil fuel prices rise considerably. The average annual import cost saving in 2011-2050 would amount to 108 bn € (08).

Total energy system costs, i.e. the amount that the rest of the economy has to pay to the energy system for the provision of energy, including capital, fuel and other costs, amounts to 2582 bn € (08) on average in each year from 2011 to 2050. This amount does not include auctioning payments, as these expenditures for individual sectors are not costs for the economy as a whole, since the auctioning revenues are recycled back to the economy. Moreover, this cost concept excludes so called disutility costs.[128]

[128] Disutility costs are a concept that tries to capture losses in utility from adaptations of individuals to policy impulses or other influences through changing behaviour and energy consumption patterns that might bring them on a lower level in their utility function. The PRIMES model, having a micro-economic foundation, deals with utility maximisation and can calculate such perceived utility losses via the concept of compensating variations (amount of additional income that would bring the individual on the same level of

With higher energy import prices, total energy system costs are 187 bn € (08) per year larger throughout the period 2011 to 2050. Under the hypothesis of low world fossil fuel prices, average annual energy system costs would decrease by 155 bn € (08) per year over the same period.

Conclusions on import price sensitivities

High world energy prices reduce CO2 and GHG emissions, while low prices exert the opposite influence. However, there are several other effects via fuel mix, electricity generation, ETS prices (given the same ETS cap across scenarios) and CCS incentives that modify the overall effect while working in different directions.

High fossil fuel prices lead to slightly higher electricity demand given the small reaction of electricity prices to increasing fuel input prices in the presence of large unrelated cost blocks such as capital costs, levies and taxes. Combined with a significant increase in the share of zero carbon (non-fossil) fuels there is lower demand for ETS allowances and therefore the ETS price decreases somewhat.

Lower fossil fuel prices give rise to the opposite effects. Energy consumption and CO2 emissions rise, however moderated by lower competitiveness of non-fossil, carbon free fuels. As an overall result, the effect of this fuel shift outweighs the effects through lower electricity production and lower CCS share, bringing about higher demand for allowances and slightly higher ETS prices.

The sensitivity cases show that significant changes in world energy prices exert only a small influence on ETS prices as long as the gas to coal price ratio does not change significantly.

This conclusion on rather limited effects of significant changes in world energy prices on EU GHG emission can also be derived by considering the above results on energy and carbon intensities. Important further rises in oil and gas import prices lead to only minor changes in CO2 emissions via limited effects on energy intensity and marginal effects through changes in fuel mix and technology deployment (carbon intensity). The CO2 effects of lower fossil fuel prices (virtual stabilisation of fossil fuel import prices) appear to be proportionately more pronounced in the long term than those from further price increases above Reference case levels. Regarding total GHG emission, the CO2 effects from changes in fossil fuel prices would be limited through countervailing effects of high fossil fuels prices through reduced carbon prices.

High fossil fuel prices limit business opportunities for energy exporters given that EU imports would decrease, most so for natural gas. Conversely, with lower fossil fuel prices, significantly higher gas deliveries to the EU can be assured. Import dependency increases with low world energy prices, whereas it stays below Reference at the current level throughout the projection period.

Electricity prices are significantly lower than Reference under low fossil fuel import prices, whereas they are significantly higher in the case that high energy import prices prevail.

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utility as experienced before the change). However, this concept has to assume that preferences and values remain the same, even over 40 years, and has to compare utility with a hypothetical state of no policy or no change in the framework conditions. Numbers in particular in the longer term are uncertain. The numbers shown above relate to costs that reflect actual payments.

Moreover, high energy import prices increase the EU's external fuel bill substantially, thereby weakening the competitiveness of the EU economy. Income that would have been used to buy domestically produced goods and services would be diverted to energy exporters with only a small part being recycled into higher EU exports into these countries. On the contrary, lower fossil fuel prices give a boost to the EU economy improving its competitiveness, also through lower costs and inflation.

The external energy bill of the EU becomes significantly larger with high world energy prices (+132 bn € (08) per year over the next 40 years), whereas this bill was reduced by 109 bn € (08) annually in the case that fossil fuel prices remained broadly at the level seen in 2010. Similarly, total energy system costs would be significantly larger with high fossil fuel prices, whereas the rest of the economy would need to pay to the energy system a significantly lower amount in case of low world energy prices.

2.4 Current Policy Initiatives scenario

This scenario reflects the Current Policy Initiatives (CPI) that are being discussed or undertaken in the EU context with a view to the 2020 Energy Strategy. This scenario does not attempt to give a full appreciation of all the results that might be expected from the Energy Strategy, nor does it mirror in detail the – future – policy adoption and implementation; it reflects the measures being proposed and discussed (for details see above under assumptions). While the measures focus on the medium term, the CPI scenario modelling evaluates also the long term consequences up to 2050 and provides thereby another benchmark for comparison with decarbonisation scenarios.

Energy demand

Primary energy consumption under CPI declines pretty strongly between 2005 and 2020 (-6.9%) and continues to do so through 2030 when it will have fallen well below the 1990 level. There is a further decline up to 2050 (-11.6% from 2005), in which year energy consumption would be 8.4% lower than in the Reference case. There are also marked changes from Reference in 2020 (-5.0%) and 2030 (-5.8%).

These energy savings from 2005 levels are brought about by a decline in final energy demand, especially in the households and services/agriculture sectors, and by efficiency improvements in energy transformation resulting from the implementation of measures in the Energy Efficiency Plan. Bottom up energy efficiency measures reverse the trend of ever increasing final consumer demand witnessed so far in statistics and many trend scenarios, including the Reference scenario in the period up to 2020.

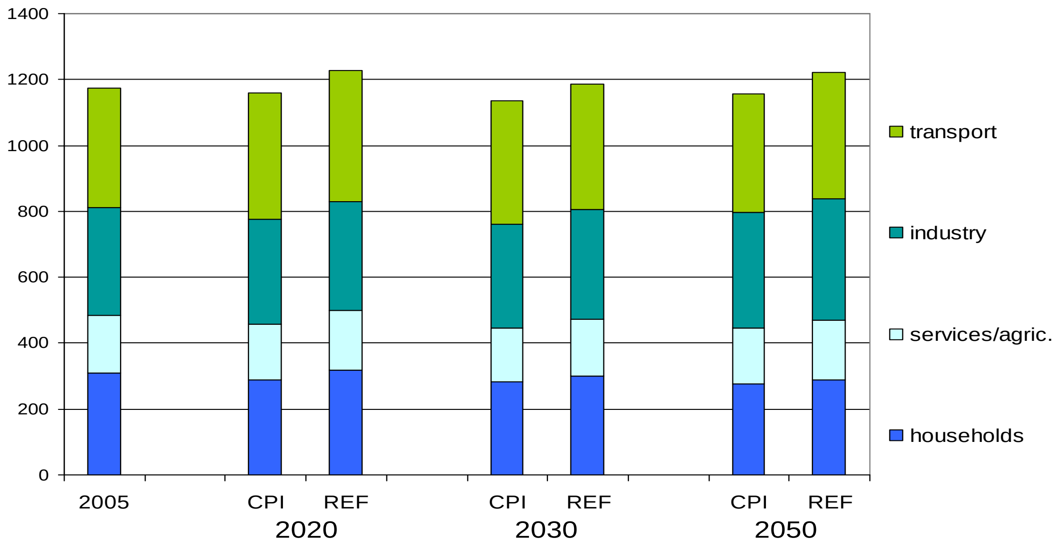
Total ***final energy demand*** reduces 1.3% from 2005 by 2020. Reductions by 2030 amount to 3.2%; thereafter final demand starts growing again slightly through 2050. Nevertheless, in 2050, CPI final demand stays 5.3% below Reference (even 5.6% for 2020 as CPI includes many energy efficiency policies to be implemented over the next few years).

Households show the greatest decrease below 2005 levels: by 6.1% up to 2020 as well as by 8.5% and 10.0% until 2030 and 2050, respectively. In 2020 household energy consumption is 8.9% below the Reference case, while this decline in 2050 amounts to 3.8%. This decline compared with Reference in 2050 is smaller given that large parts of the energy efficiency potential captured in CPI in the earlier years is taken up the Reference case in later years. Energy efficiency measures linked especially to Eco-design regulations and savings obligations on energy providers with respect to their customers are instrumental for this pronounced decline in CPI. Moreover, the effects on final consumer prices stemming from the proposed Energy taxation directive contribute towards reducing energy consumption.

Energy demand in services and agriculture also decreases significantly by 5.5% and 6.7% in 2005-2020 and 2005-2030, respectively. After 2030, final energy demand in this sector would resume its rising trend reflecting growing economic activity. In any case, demand in services/agriculture falls well below Reference case levels through 2050, with demand being 7.0% lower in 2050 and even 7.8 % lower in 2020. Eco-design measures, faster renovation rates for existing - especially public - buildings, promotion of energy service companies as well as energy savings obligations are key policy measures to bring about such savings. The new energy taxation directive also contributes to this decline.

Energy consumption in industry also declines from 2005 levels: by 2.3% up to 2020 and by 3.7% up to 2030. Thereafter, industrial energy demand starts growing slightly without reaching again the current level. Industrial energy demand stays below Reference scenario levels: by 5.5% in 2030 and 5.1% in 2050. Energy service companies, eco-design and energy savings obligations are among the drivers for bringing about such savings, which are somewhat moderated by healthy production growth and by the feedbacks through lower ETS prices regarding certain industrial branches. Such feedbacks stem from energy/electricity savings that reduce the demand for ETS allowances and therefore ETS prices (see below).

Figure 17: Final Energy Consumption by sector in Current Policy Initiatives and Reference Scenarios (in Mtoe)



Transport energy consumption is comparatively little affected by current energy policy initiatives. Energy consumption continues to increase, exceeding the 2005 level by 5.6% in 2020. After 2025, transport energy consumption starts declining slowly, returning the 2005 level by 2050. Compared with Reference, consumption remains below the levels reached throughout the projection period (by 1.7% in 2030 and 5.7% in 2050). Changes from Reference are brought about in particular by the proposed new energy taxation system and through the somewhat more favourable policy environment for electric and plug-in hybrid vehicles, while CO2 standards exert only a limited influence given that the CO2 from cars regulation is already included in the Reference case.

While final energy demand for oil, gas and coal would continuously decline up to 2050, demand for electricity, heat and RES would increase. Most important in absolute terms is the increase in electricity demand, which rises 43% between 2005 and 2050. Nevertheless, electricity demand in CPI falls well below electricity use in Reference, reflecting measures in the Energy Efficiency Plan and revised Energy taxation Directive. CPI electricity consumption is down on Reference by 6.5% in 2030 and 4.3% in 2050.

Demand for distributed heat is rising compared to current level but is 1-2% lower than in the Reference scenario reflecting effects of measures in the Energy Efficiency Plan, in particular more efficient heating systems in houses. Heat demand in residential sector is 7% lower in 2020 compared to the Reference scenario. The difference is much lower towards the end of the projection period (1-2%) as the measures included in the Energy Efficiency Plan target short to medium term.

Power generation

Rising electricity demand over time will require a similar increase in power generation and a lot of new investment in power generation and grids. Even though energy efficiency measures bring about lower electricity demand and production compared with Reference (see table 12) gross electricity production is expected to increase 41% by 2050 under CPI. Electricity based on RES is expected to make major inroads reaching a share in power generation of close to 50% in 2050.

Table 12: Electricity related indicators in CPI scenario and differences from Reference

	Current Policy Intitiatives				Difference from Reference		
	2005	2020	2030	2050	2020	2030	2050
Gross electricity generation (TWh)	3274	3645	3780	4621	-121	-286	-311
Shares in gross electricity generation					in percentage points		
RES share	14,3%	34,5%	43,6%	48,8%	1,2%	3,1%	8,5%
Nuclear share	30,5%	23,9%	20,7%	20,6%	0,8%	-3,8%	-5,8%
Fossil fuel share	55,2%	41,6%	35,7%	30,6%	-2,0%	0,7%	-2,7%
CCS share	0,0%	0,7%	0,8%	7,6%	-0,6%	-2,1%	-10,2%
Prices in €							
ETS (€(08)/t CO2)	0,0	15,0	32,0	51,0	-2,5	-8,0	1,0
Average electricity price (in €(08)/MWh)	110,1	148,5	159,0	159,9	0,0	1,3	6,1

The CPI scenario takes account of the post Fukushima policy change in Member States, notably the abandoning of the nuclear programme in Italy and the new nuclear approach in Germany modifying somewhat the previously decided nuclear phase-out Moreover, it includes other changes and new initiatives, such as the nuclear stress tests that tend to increase costs for new power plants and retrofitting.[129]

[129] There are slightly higher risk premiums for new nuclear investment in this scenario, considering that investors might factor into their decisions the possibility that the policy reaction to any hypothetical further nuclear accident may affect the nuclear plants under investment consideration, even though such an accident could happen rather far away geographically. Requiring thereby a slightly higher return on investment to cover this political risk has also certain effects on new nuclear investment. As a result of these changes in the policy

The slightly higher nuclear share in 2020 reflects lower total electricity production and the modification in the nuclear phase-out provisions between the German nuclear law before the extension of nuclear plant lifetimes in autumn 2010 (mirrored in the Reference case) and the new schedule. The new phase-out schedule includes faster closure of nuclear plants in the next few years, compensated by slightly higher capacity around 2020, keeping cumulative allowed nuclear generation (in TWh) at the same level.

Fossil fuel based power generation falls significantly throughout the projection period; its share diminishes from 55% to just over 30% in 2050. Solid fuels lose most, with losses for gas based power generation remaining rather limited.

The CPI scenario has significantly lower CCS penetration in 2020 compared to the quite optimistic national plans as envisaged in 2009 (Reference scenario) and rather moderate recent progress in demonstration plants. This concerns also potential storage sites. In medium term, lower ETS price in the CPI scenario, reflecting lower energy demand due to additional energy efficiency measures, affects commercial viability of CCS. In the long term, lower numbers compared with Reference are also a result of the strong decline in solid fuels and gas based power generation.

ETS prices are lower in CPI compared with Reference in the medium to long term. The CCS incentive through carbon prices is reduced by 20% from 40 €/tCO2 to 32€/t CO2 in 2030. Consequently, the CCS share in CPI in 2030 amounts to 1% and rises thereafter significantly with high ETS prices to reach 8% in 2050. The energy efficiency measures in CPI cut electricity and fuel demand and the need for allowances, which in a context of an unchanged ETS cap leads to lower ETS prices. This limits - as a side effect - also the incentives for CCS.

Average electricity prices are slightly higher than Reference over the projection period (0.8% in 2030 and 4.0% in 2050) reflecting the lower share of nuclear post Fukushima and high investments for new electricity generation capacity, especially RES.

Fuel mix

These changes in the demand side and in power generation have significant impacts on primary energy consumption and the fuel mix. Primary energy demand declines 200 Mtoe up to 2050, when it remains 150 Mtoe below the Reference case level.

In the long term to 2050, both fossil fuels and, to a limited extent, nuclear reduce their importance in the fuel mix, with solids undergoing the greatest decline (minus 8 percentage points in 2005-2050). The share of nuclear is lower also in comparison to the Reference scenario due to changes in nuclear assumptions. RES are the clear winner of this structural change, making them in 2050 the second most important fuel after oil. RES gain 16 percentage points from today's level in terms of primary energy and about 20 percentage points when accounted for in terms of gross final energy demand.

Oil remains the most important fuel throughout the projection period as the fuel mix in transport remains largely unchanged. Nevertheless oil loses 5 percentage points by 2050.With primary energy demand declining, the fuels used most in sectors that are least affected by

environment, the nuclear share is somewhat lower than Reference in the long term, for which the Italian withdrawal from nuclear is particularly important. Moreover, lower ETS prices in CPI reduce the economic advantages connected to nuclear investments.

current energy policies, such as oil in transport, are able to score a slightly higher share in the fuel mix compared with Reference.

Post Fukushima changes in nuclear (discussed above) reduce the role on nuclear compared with Reference. In this new policy environment gas and RES replace nuclear and thereby increase their share over Reference scenario levels.

These changes towards a significantly greater RES contribution bring about an important decline in carbon intensity over time (by a third between 2005 and 2050). However, with respect to Reference, there is a certain increase in carbon intensity, given that CPI relies less on nuclear and that CCS penetrates more slowly. Carbon intensity in 2050 exceeds the Reference case level by 7.7%.

Table 13: Fuel mix of primary energy consumption in CPI and Reference

	Current Policy Intitiatives				CPI: difference	Difference from Reference		
	2005	2020	2030	2050	2005-2050	2020	2030	2050
Primary energy consumption (Mtoe)	1826	1700	1629	1615	-211	-90	-99	-148
Shares in primary energy					in percentage points			
Oil	37,1%	34,7%	34,1%	32,0%	-5,1%	0,3%	1,2%	0,3%
Natural gas	24,4%	22,4%	22,7%	21,9%	-2,5%	-0,6%	0,5%	1,6%
Solid fuels	17,5%	14,0%	12,0%	9,4%	-8,1%	-0,7%	-0,5%	-1,9%
Nuclear	14,1%	13,2%	12,1%	13,5%	-0,5%	0,7%	-2,2%	-3,2%
RES	6,8%	15,8%	19,3%	23,3%	16,4%	0,3%	0,9%	3,3%
share in final energy	8,6%	20,6%	24,6%	29,0%	20,3%	0,5%	0,8%	3,5%

CO2 and GHG emissions

In spite of this deterioration of carbon intensity there is a somewhat greater CO2 reduction in CPI than in Reference; CO2 emissions in 2050 are slightly lower than in the Reference scenario. This development is due to greater energy intensity improvements brought about by vigorous energy efficiency policies, which overcompensates the worsening of carbon intensity due especially to lower use of nuclear and CCS.

This energy intensity effect on CO2 emissions is somewhat moderated by the effect of energy efficiency on carbon intensity via ETS prices. Declining ETS prices, triggered to some extent by lower energy demand, give rise to lower incentives for investing in e.g. CCS and nuclear, thereby giving rise to somewhat higher carbon intensity.

Table 14: CO2 emissions and drivers in CPI and Reference scenarios

	Current Policy Initiatives scenario			Reference
	2005-2030	2030-2050	2005-2050	2005-2050
	average annual change (% pa)			
GDP	1,7%	1,5%	1,6%	1,6%
Energy intensity	-2,1%	-1,5%	-1,8%	-1,6%
Carbon intensity	-0,8%	-1,0%	-0,9%	-1,0%
CO2 emissions	-1,2%	-1,0%	-1,1%	-1,1%
Total CO2 reduction (%)	-26,4%	-18,5%	-40,0%	-39,2%

Energy intensity improvements are particularly pronounced in the earlier years of the projection period thanks to vigorous new energy saving measures targeting in particular the short and medium term. In total CO2 emissions reduce 40% between 2005 and 2050, up one percentage point from what would be achieved under reference case developments. With respect to 1990 CO2 emissions in CPI decline by 41.3% up to 2050. The Reference scenario has a decrease of 40.4%.

Total GHG emissions in 2050 decrease 38.6% below the 1990 level, which is slightly less than in the Reference case (-39.7%), given the significantly lower carbon price until just before 2050, reflecting especially successful energy efficiency policies. This means, on the other hand, that total GHG emissions reduce faster in CPI than in Reference in the time horizon to 2020 and also to 2030.

Energy imports / security of supply

Lower energy demand and the changes in the political environment after the Japanese nuclear accident of March 2011 give rise to significant changes in EU energy production, which is down on Reference by 9.0% in 2050. Nuclear production sinks 25.8% compared with Reference in 2050, while RES production is 7.8% higher. Also gas production is seen in a more favourable light (+4.0%).

Despite lower indigenous production, energy imports are 7.5% lower in 2050 than in the Reference scenario due to the policy measures, notably on energy efficiency, included in CPI. Nevertheless, net energy imports are expected to broadly stabilise throughout the projection period (peaking in 2015, when they exceed the 2005 level by 6.4%, before declining 7.5% up to 2050).

Biomass and natural gas imports increase significantly, whereas oil imports decline moderately and solids see their imports sink considerably. Gas imports in 2050 are expected to be 26% higher than they were in 2005. Oil imports decrease 6% over this period, while solid fuel imports plummet 56%.

Import dependency remains broadly unchanged from Reference case and also current levels. Up to 2020, this indicator rises from 54% at present to reach 56%. This is one percentage point less than in Reference, reflecting the impact of efficiency measures mainly on imported fuels. In 2030, import dependency reaches 57.5%, up one percentage point on Reference, which is largely a result of lower nuclear availability. In 2050, this indicator amounts to 58% in both CPI and Reference.

Conclusions on Current Policy Initiatives scenario

As a result of current policy initiatives, energy consumption is expected to be reduced significantly. The decline in both final and primary energy consumption is most pronounced in the medium term, for which most of the measures have been designed. The implementation of the Energy Efficiency Plan brings important reductions in final energy demand, especially in the household and services/agriculture sectors.

In terms of primary energy, consumption sinks throughout the projection period, falling below the 1990 level by 2030 with a continuing decline thereafter. In 2050, energy demand decreases 12% below the 2005 level. As a result, energy intensity improves 1.8% pa, which is 0.2 percentage points up from the number in the Reference case.

This decline in energy consumption is connected with significant changes in the fuel mix, which are also linked, among other things, to post Fukushima changes in the policy environment for nuclear energy in several Member States. Compared with Reference, the contribution of nuclear and solid fuels declines, while oil, gas and in particular RES account for higher shares in primary energy consumption in 2050.

In a comparison over time, fossil fuels lose as much as 16 percentage points from 2005 to 2050, of which solid fuels account for 8 percentage points, oil for 5 and gas for 3 percentage points. Renewables are the clear winner, benefiting from several policies not even directly targeting RES and of course those measures included in the 2008 Energy and climate package. The RES share in primary energy rises 16 percentage points, while the nuclear share remains almost constant (only a slight decrease post Fukushima).

The RES share in gross final energy consumption increases 20 percentage points from 2005 by 2050 when it reaches 29%. Also the RES shares in transport and power generation rise considerably reaching 49% and 20% in 2050, respectively. Taking a 2030 perspective, the overall RES share in final demand grows 16 percentage points to reach 25% in 2030 under current policy initiatives. RES in transport account for 13%. RES contribute 44% to power generation.

Electricity generation also falls compared with Reference, given successfully implemented energy efficiency policies, but would exceed the 2005 level by 41% in 2050. Again, there are significant changes in the generation mix, which also explain to a large extent the fuel mix changes at the primary energy level. Almost half of power generation in 2050 would be based on RES, up from just 14% in 2005. Nuclear loses around 10 percentage points share in power generation in 2005-2050 given strongly rising electricity production and the recent changes in the policy environment for nuclear. The share of fossil fuel based electricity generation diminishes from 55% in 2050 to just over 30% in 2050 mainly due to reductions in solid fired power generation.

These changes in power generation towards lower solid fuel contribution compared with Reference entail lower demand for ETS allowances giving rise to lower ETS prices thus also providing fewer incentives for CCS. As an overall result of these simultaneous changes, the

ETS price falls 20% below the Reference level in 2030. In 2030 almost 1% of gross power generation undergoes CCS, while this share rises to 8% in 2050.

Developments of the fuel mix and the CCS penetration bring about a 0.9% pa decline in carbon intensity from 2005 to 2050. This decline in carbon intensity is marginally smaller than the one under Reference developments, reflecting in particular post Fukushima changes for nuclear and lower medium term ETS prices following strong energy efficiency measures, which, as an indirect effect, limit CCS penetration.

Nevertheless, energy related CO2 emissions reduce slightly more than under Reference developments. CO2 emissions in CPI sink 41.3% while the decline amounts to 40.4%. Total GHG emissions in CPI reduce 38.6% below 1990 by 2050.

Total energy imports broadly stabilise throughout the projection period, despite significant increases in biomass and natural gas imports. Oil and notably solid fuels import decline. Import dependency remains broadly unchanged from Reference case and also current levels.

The CPI scenario involves higher system costs stemming notably from the additional investment triggered through additional energy efficiency requirements and the restructuring of the energy and transport systems including the lower nuclear contribution due to upward revised costs and more Member States renouncing the nuclear option. Moreover the inclusion of the Energy taxation directive adds to these additional costs. Taking into account the fuel savings from energy efficiency measures as well as the taxation induced savings, energy system costs in the period 2011 to 2050 increase by an annual amount of bn 37 €(08). These cost estimates do not consider possible changes in the utility levels of consumers regarding the behavioural changes induced that are, in any case, not directly measurable and can only be captured in the modelling indirectly via the concept of compensating variations.

Average electricity prices rise at only a slightly faster pace compared with Reference developments. In 2030, the average electricity price exceeds Reference by only 1%; this price increase becomes 4% in 2050.

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Part 2/2

COMMISSION STAFF WORKING PAPER

Impact Assessment

Accompanying the document

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Energy Roadmap 2050

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Annex 1 Scenarios – assumptions and results

PART B: DECARBONISATION SCENARIOS

1. ASSUMPTIONS

1.1 Macroeconomic and demographic assumptions

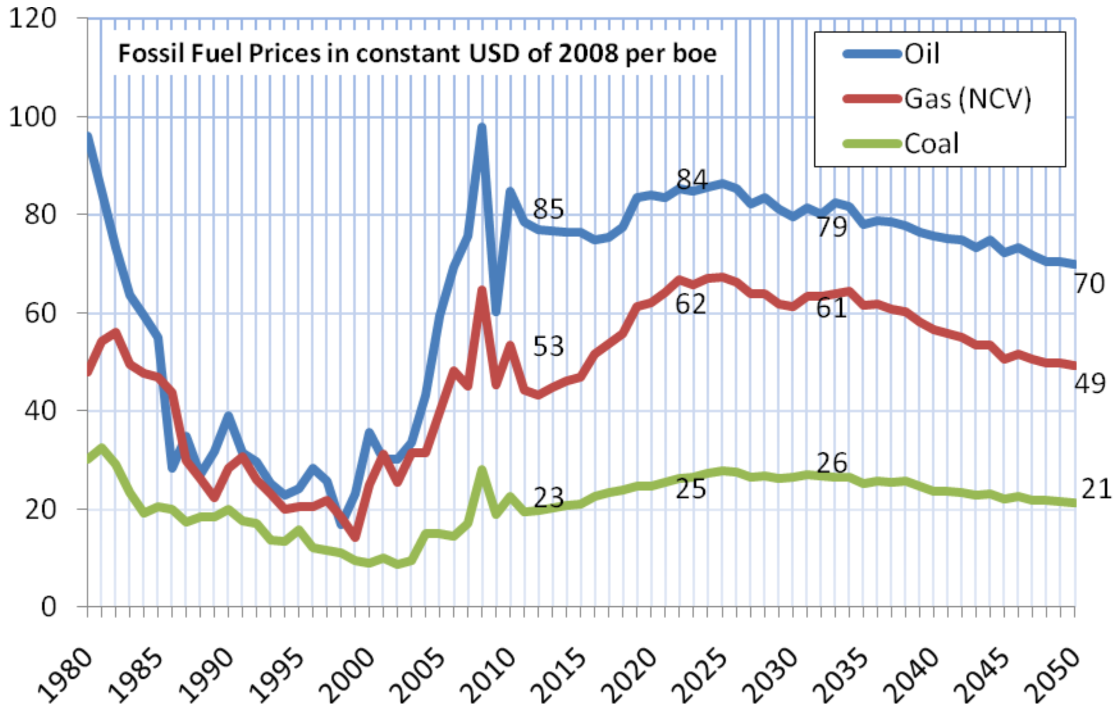
On the basis of the European Council's objective for EU decarbonisation of at least 80% below 1990 by 2050 in the context of necessary reductions by developed countries as a group[1] it is assumed that competitiveness effects throughout decarbonisation would be rather limited. Therefore, the decarbonisation scenarios are based on the same demographic and macroeconomic assumptions as the Reference scenario and Current Policy Initiatives scenario. Such an assumption also facilitates comparison of the energy results across scenarios. These macro-economic (sectoral production) assumptions also hold for energy intensive industries. However, under fragmented action, measures against carbon leakage may be necessary. The analysis of this particular case (see below) deals with energy and emission effects of such measures, but does not address potential changes in sectoral production levels under fragmented action. The aim of measures against carbon leakage is indeed to avoid such relocation of energy intensive production.

1.2 Energy import prices

The decarbonisation scenarios are based on "global climate action" price trajectories for oil, gas and coal[2] reflecting that global action on decarbonisation will reduce fossil fuel demand worldwide and will therefore have a downward effect on fossil fuel prices. Oil, gas and coal prices are therefore lower than in the Reference scenario and Current Policy Initiative scenario. Their trajectories are an outcome of the global analysis in the Low carbon Economy Roadmap, which is similar to recent IEA projections that assessed the impacts of ambitious climate policies[3].

[1] European Council, 29/30 October 2009.
[2] See Impact assessment accompanying Communication on Low Carbon Economy Roadmap SEC(2011)288
[3] International Energy Agency, World Energy Outlook 2009, Energy Technology Perspectives 2010

Figure 18: Fossil fuel prices in the decarbonisation scenarios



1.3 Policy assumptions

In addition to policy assumptions in the Current Policy Initiatives scenario, the following policies and measures were added to scenarios:

Table 15 Measures included in all decarbonisation scenarios

1	Climate policies for respecting carbon constraints to reach 85% energy related CO2 reductions by 2050 (40% by 2030), consistent with 80% reduction of total GHG emissions according to the "Roadmap for moving to a competitive low carbon economy in 2050" (including achievement of cumulative carbon cap) in a cost effective way	Supplementary to specific energy policies in the scenario, ETS prices and carbon values for non ETS sectors are determined in such a way as to reach the 2050 reduction goal; ETS and non ETS sectors use equal carbon prices/values (from 2025 onwards); cumulative emissions are similar across scenarios
2	Stronger RES facilitation policies	Represented by higher RES-values in the model. These facilitating RES policies include for example the availability of more sites for RES, easier licensing of RES installations, greater acceptance and support deriving from the improvement of local economies and industrial development; operational aids remain at the same level as in the REF/CPI scenarios.
3	Transport measures	Energy efficiency standards, internal market, infrastructure, pricing and transport planning measures leading to more fuel-efficient transport means and some modal shift Encourage the deployment of clean energy carriers by establishing the necessary supporting infrastructures[4]

[4] The decarbonisation scenarios reflect the transport policy measures included in the White Paper "Roadmap to a Single Transport Area – Towards a competitive and resource efficient transport system" (COM (2011) 144) with highest impact on energy demand in transport.

4	Guarantee funds for all low carbon generation technologies	The model reflects support to early demonstration and first of a kind commercial plants for all innovative low-carbon technologies in the energy sector (nuclear, RES and their infrastructure needs, CCS, etc.).
5	Storage and interconnections	Higher penetration of variable generation leading occasionally to excess electricity is dealt with by increased pump storage and more interconnection capacity. Moreover, large parts of such excess electricity generation from variable sources is transformed into hydrogen, which is fed, up to a certain degree, into the natural gas grid, thereby providing a means for (indirect) storage of electricity and reducing the carbon content of gas delivered to final consumers enabling deeper emission cuts. Where for technical or economic reasons, simulated in the model, feeding into the natural gas grid is not feasible, excess electricity (mainly from RES) is stored in form of hydrogen at times of excess supply and transformed back into electricity when demand exceeds supply. (Hydrogen storage is used to a different degree in various decarbonisation scenarios, see also measures under Scenario 4).

Scenario 2: High energy efficiency

This scenario is driven by a political commitment of very high primary energy savings by 2050. It includes a very stringent implementation of the Energy Efficiency Plan and aims at reaching close to 20% energy savings by 2020. Strong energy efficiency policies are also pursued thereafter.

Table 16 Policies/measures included (in addition to measures in table 15):

	Measure	**How it is reflected in the model**
1	Additional strong minimum requirements for appliances	Progressive adaptation of modelling parameters for different product groups. As requirements concern only new products, the effect will be gradual.
2	High renovation rates for existing buildings due to better/more financing and planned obligations for public buildings (more than 2% refurbishment per year)	Change of drivers (ESCOs, energy utilities obligation, energy audits) influence stock – flow parameters in the model reflecting higher renovation rates (higher than 2% pa), with account being taken of tougher requirements for public sector through specific treatment of the non-market services sector
3	Passive houses standards after 2020	All new houses after 2020 comply with passive house standards - around 20-50 KWh/m2 (depending on the country) which might to a large extent be of renewable origin
4	Marked penetration of ESCOs and higher financing availability	Enabling role of ESCOs is reflected in lower discount rates for household consumers (from 17.5% to 16% in 2015, 14% in 2020, 13% in 2025 and **12%** from 2030 onwards) and for industry, agriculture and services (from 12% to 11% by 2015 and to **10%** from 2020 onwards)
5	Obligation of utilities to achieve energy savings in their customers' energy use over 1.5% per year (up to 2020)	Induce more energy efficiency mainly in residential and tertiary sectors by imposing an efficiency value for grid bound energy sources

		(electricity, gas, heat)
6	Strong minimum requirements for energy generation, transmission and distribution including obligation that existing energy generation installations are upgraded to the BAT every time their permit needs to be updated	Higher efficiency of power plants through removing less efficient items from the generation portfolio, allowing however for efficiency losses where CCS is deployed Less transmission and distribution losses
7	Full roll-out of smart grids, smart metering	Enabling more efficiency and decentralised RES; Reflected as costs in the distribution grid costs, electricity prices and overall costs of the energy system
8	Significant RES highly decentralised generation	More advanced power dispatching and ancillary services to support reliability of power supply Higher penetration of small wind, solar and hydro

Scenario 3: Diversified supply technologies scenario

This option is mainly driven by carbon prices and carbon values (equal for ETS and non ETS sectors). Carbon values are a still undefined proxy for policy measures that bring about emission reduction. They do not represent a cost to economic actors outside EU ETS (where they coincide with the EU ETS price), but are economic drivers that change decision making of the modelled agents. Yet, the changes triggered by carbon values may entail costs (e.g. for investment in energy savings or for fuel switching), which are accounted for in the modelling framework. They are applied to all sectors and greenhouse gas emissions, covering ETS and Non ETS sectors. As economic drivers, they influence technology choices and demand behaviour. Their respective level is not an assumption but a result of the modelling depending among other things on the level of ambition in GHG reduction. The modelling applies equal carbon values across sectors and ensures thereby efficient reductions across sectors.

This option assumes acceptance of nuclear and CCS and development of RES facilitation policies. It reproduces the "Effective and widely accepted technologies" scenario used in the Low Carbon Economy Roadmap and Roadmap on Transport on the basis of scenario 1bis.

Table 17 Policies/measures included (in addition to measures in table 15):

	Measure	How it is reflected in the model
1	MS and investors have confidence in CCS as a credible and commercially viable technology; acceptance of storage and CO2 networks is high	
2	MS, investors and society at large have confidence in nuclear as safety is considered adequate and waste issues are solved	Applicable for all countries that have not ruled out the use of nuclear, i.e. Germany and Belgium for the longer term and the currently non-nuclear countries except for Poland

Scenario 4: High RES

This scenario aims at achieving very high overall RES share and very high RES penetration in power generation (around 90% share and close to 100% related to final consumption). Recalling security of supply objectives, this would be based on increasing domestic RES supply including off-shore wind from the North Sea; significant CSP and storage development, increased heat pump penetration for heating and significant micro power generation (PV, small scale wind, etc.). Regarding assumptions for the demand sectors, scenario 4 is similar to scenario 3, with the exception that RES are more intensively facilitated.

Table 18 Policies/measures included (in addition to measures in table 15):

	Measure	How it is reflected in the model
1	Facilitation and enabling policies (permitting, preferential access to the grid)	Represented by significantly higher RES-values in the model than in other decarbonisation scenarios; these RES facilitating policies include for example lower lead times in construction, and involve greater progress on learning curves (e.g. small scale PV and wind) based on higher production.
2	Market integration allowing for more RES trade	Use of cooperation mechanisms or convergent support schemes coupled with declining costs/support result in optimal allocation of RES development, depending also on adequate and timely expansion of interconnection capacity (point 4);
3	Stronger policy measures in the power generation, heating and transport sectors in order to achieve high share of RES in overall energy consumption in particular in household micro power generation and increased power production at the distribution level.	Higher use of heat pumps, significant penetration of passive houses with integrated RES reflected through faster learning rates (cost reductions), higher penetration rates (e.g. due to RES building/refurbishing requirements)
4	Infrastructure, back-up, storage and demand side management	Substantial increase in interconnectors and higher net transfer capacities including DC lines from North Sea to the centre of Europe. Back-up functions done by biomass and gas fired plants. Sufficient storage capacity is provided (pumped storage, CSP, hydrogen). Smart metering allows time and supply situation dependent electricity use (peak/off-peak) reducing needs for storing variable RES electricity. All these measures allow for exploiting greater potentials for off-shore wind in the North Sea.

Scenario 5: Delayed CCS

The delayed CCS scenario shows consequences of a delay in the development of CCS, reflecting acceptance difficulties for CCS regarding storage sites and transport; large scale development of CCS is therefore assumed feasible only after 2040.

Table 19 Policies/measures included (in addition to measures in table 15):

	Measure	How it is reflected in the model
1	**Acceptance difficulties for CCS regarding storage sites and transport, which allow large scale development only after 2040.**	Shift of cost-potential curves to the left (higher costs reflecting delays and public opposition). The learning curve for CCS is also delayed accordingly, resulting in higher capital costs for CCS than in scenario 3
2	MS , investors and society at large have confidence in nuclear as safety is considered adequate and waste issues are solved	Low risk premiums for nuclear Applicable for all countries that have not ruled out the use of nuclear, i.e. Germany and Belgium for the longer term and the currently non-nuclear countries except for Poland

Scenario 6: Low nuclear

This scenario shows consequences of a low public acceptance of nuclear power plants leading to cancellation of investment projects that are currently under consideration and no life time extension after 2030. This leads to higher deployment of the substitute technologies CCS from fossil fuels on economic grounds.

Table 20 Policies/measures included (in addition to measures in table 15):

	Measure	How it is reflected in the model
1	**Political decisions based on perceived risks associated with waste and safety (especially in the aftermath of the Fukushima accident) leading to no new nuclear plants being build besides the ones presently under construction: 1600 MWe in Finland, 2x1600 MWe in France and 2x505 MWe in Slovakia. Moreover, the recourse to deciding instead on nuclear lifetime extension is available only up to 2030.**	No extension of nuclear lifetime on economic grounds after 2030 No new nuclear plants are being built besides reactors under construction : 1600 MW in FIN; 2*1600 MW in FR and 2*505 MW in SK
2	MS and investors have confidence in CCS as a credible and commercially viable technology; acceptance of storage and CO2 networks is high	Low risk premiums for CCS

1.4 Assumptions about energy infrastructure development

Infrastructure modelling for decarbonisation scenarios was done similarly to the approach described in Part A, section 1.4 for the Reference and Current Policy initiatives scenarios.

For decarbonisation scenarios the analysis done showed that except for very high RES penetration, the 2020 interconnection capacity would allow for most intra-EU electricity trade provided that some bottlenecks would be dealt with. The identified bottlenecks concerns interconnections around Germany, in Austria-Italy-Slovenia, Balkans and Denmark-Sweden. Greater investment and capacity for these specific links were assumed.

For very high RES penetration, which involves much more RES based electricity trade, stronger growth of interconnection capacity will be required. Under the assumptions of this scenario, full exploitation of off-shore wind potential at North Sea is foreseen. It is assumed that a dense DC interconnection system will develop mainly offshore but also partly onshore, to facilitate power flows from the North Sea offshore wind parks to consumption centres. In this scenario, the links of Sweden with Poland, Sweden with Lithuania, Austria with Italy, France with Italy and links in the Balkan region appear to be congested and need to be reinforced mainly with DC lines.

For more details on the modelling approach and results see Attachment 2.

1.5 Technology assumptions

Many technology assumptions are the same as in the Reference scenario and Current Policy Initiatives scenario (with revised assumptions about nuclear). In the decarbonisation scenarios, however, there are additional features and mechanisms that produce high decarbonisation and technology penetration.

Whereas all decarbonisation scenarios rely on technologies that exist today, they might become commercially mature only over time supported also by decarbonisation requirements. The uptake of the technologies is endogenous in the scenarios with their large-scale deployment leading to lower cost and higher performance, which correspond to a fully mature commercial stage.

All scenarios simulate merit order dispatching for power generation with contribution of variable generation from renewables. Electricity balancing and reliability is ensured endogenously by various means such as import and export flows (in case of high RES it is facilitated by expanding interconnections), investment in flexible thermal units, pumped storage and if required hydrogen based storage. In this latter case, excess variable generation from RES at times of lower demand may be used to produce hydrogen via electrolysis which is then used to produce electricity in turbine based power plants when electricity demand exceeds production from RES and other available sources (e.g. in situations of high demand).

The modelling approach also considers the possibility to mix hydrogen produced through electrolysis in the low and medium pressure natural gas distribution system (up to 30%) in order to reduce the average emission factor of the supplied blend, thereby contributing to the decarbonisation of final energy consumption.

Photovoltaic in High RES Scenario evolves along more optimistic trajectories than in the Reference scenario, as it is presumed that the higher penetration of the technology leads to stronger learning by doing. The higher uptake of RES technologies is driven mainly by the lower cost potentials for RES power, which are due to policies facilitating access to resources and sites.

A further change is in the Delayed CCS scenario where the development of CCS is delayed, and does not reach the same levels of development as in the other scenarios.

There is also faster progress in energy efficiency related technologies due to bigger scale and carbon prices effects. The energy technologies on the demand side follow a different development from the Reference scenario variants. In any situation there are different choices to consumers regarding the energy performance of appliances, buildings and equipment (evident from e.g. energy labelling where such transparency is provided by legislation). In decarbonisation scenarios, there are stronger shifts towards the more efficient technology vintages, which improve the average energy efficiency of a given energy use (e.g. of the average lighting appliance) compared to the Reference scenario variants. Energy efficiency progress is therefore supported by consumer choice effects similar to increased learning by doing driven by consumers opting for the more efficient available technologies.

The assumptions on the battery costs for the transport sector were developed along the lines of the White Paper on a Roadmap to a Single Transport Area. Efficiency improvements of ICE vehicles also occur in response to carbon values, making the overall vehicle fleet more efficient than in the Reference scenario and its variants. However, the following decarbonisation scenarios do not produce the same energy related transport outcome due to the fact that these scenarios do not handle the same transport details and that the overall framework conditions are different according to the scenario. In particular, the penetration of some alternative propulsion technologies (electric vehicles, hydrogen, etc.) might be somewhat different.

1.6 Drivers

An internal greenhouse gas emission reduction contribution of around 80% in 2050 is taken as the key constraint for exploring different scenarios. To ensure that decarbonisation efforts are comparable across options and scenarios, the equalisation of cumulative emissions across scenarios is used as an additional constraint, underlining the importance of the climate impacts of cumulative emissions over the whole period until 2050 (and beyond). The corresponding decarbonisation effort from energy related CO2 emissions is 85% CO2 reductions compared to 1990, as demonstrated by the modelling underlying the Low Carbon Economy Roadmap of March 2011.

Common carbon values applied to all sectors and greenhouse gas emissions, covering ETS and Non ETS sectors, are used as key driver to reach the emission reductions and to ensure cost efficient reductions across sectors. As economic drivers, they influence technology choices and demand behaviour, in addition to the energy policies mirrored in the various scenarios for the Energy Roadmap. The respective level of carbon values is not an assumption but a result of the modelling.

Another important driver concerns international energy prices. Given that these scenarios assume global action, significantly lower fossil fuel prices are assumed than those in the reference and Current Policy Initiatives scenarios. Their order of magnitude has been set at a similar level as the results of the global analysis done for the Low Carbon economy Roadmap and recent IEA projections which assessed the impacts of ambitious climate policies.

To increase the penetration of renewable energy sources the RES-value was increased compared to the Reference scenario. In 2050, the RES-value in the decarbonisation scenarios is twice as high as in the current trend cases: instead of 35 €/MWh in Reference and CPI it amounts to 71 €/MWh in all decarbonisation scenarios, except for the high RES scenario, in which RES support is much more pronounced (RES-value of 382 €/MWh). The RES-value is a modelling tool used to reflect the marginal value of not explicitly modelled facilitation RES policies. These facilitating RES policies include for example the availability of more sites for RES, easier licensing of RES installations, benefits deriving from the improvement of local economies and industrial development. In High RES scenario the RES-value is the shadow value associated with the additional target of maximisation of the RES share in power generation and in the overall energy mix.

2. RESULTS

2.1 Overview: outcome for the four main strategic directions to decarbonisation

Decarbonisation can be achieved through energy efficiency, renewables, nuclear or CCS. Pursuing each of these main directions can bring the energy system a long way towards the decarbonisation objective of reducing energy related CO2 emissions by 85% below 1990 by 2050. The policy options (scenarios) proposed explore 5 different combinations of the four decarbonisation options. Decarbonisation options are never explored in isolation as interaction of different elements will necessarily be included in any scenario that evaluates the entire energy system. Moreover, the climate change issue is about atmospheric concentrations of GHG, i.e. with the long lifetimes of gases involved it is essentially about cumulative emissions. All scenarios achieve also the same level of cumulative GHG emissions. This makes energy, environmental and economic impacts comparable across the scenarios.

Energy Efficiency

Energy Efficiency is a key ingredient in all the decarbonisation pathways examined. Its contribution is most important in the Energy Efficiency scenario (Scenario 2). Energy savings in 2050 from 2005 (virtually the peak energy consumption year) amount to 41%, while GDP more than doubles over the same period of time (+104%). The lowest contribution from energy efficiency towards decarbonisation comes in the Delayed CCS scenario, having a high nuclear contribution, in which primary energy consumption declines 32% between 2005 and 2050. As GDP does not change between scenarios, these energy savings from 2005 are entirely due to energy efficiency gains in a broad sense (including structural change), but not involving income losses.

In the Energy Efficiency scenario, one unit of GDP in 2050 requires 71% less energy input than in 2005. The average annual improvement in energy intensity (primary energy consumption / GDP) amounts to 2.7% pa, which is almost a doubling from historical trends (1.4% pa in 1990 to 2005 including the major efficiency raising restructuring in former centrally planned economies). All the decarbonisation scenarios have energy intensity improvements around 2.5% pa given e.g. synergies between energy efficiency and RES.

Energy savings in the High RES scenario are almost as high as in the Energy Efficiency case (minus 38% for energy consumption in 2050 compared to 2005 instead of minus 41%), this is however achieved by different means: the energy efficiency scenario focuses on direct impacts on final demand, whereas energy savings in the high RES case come largely through highly efficient RES technologies replacing less efficient nuclear and fossil fuel technologies.

A clear result concerning the strategic energy efficiency direction is that a substantial speeding up of energy efficiency improvements from historical trends is crucial for achieving the decarbonisation objective.

RES

RES, too, are a key ingredient in any decarbonisation strategy. The RES share in gross final energy consumption (i.e. the definition for the existing 20% target) rises to at least 55% in 2050.

In the High RES scenario the RES share in gross final energy consumption reaches 75%, up 65 percentage points from current levels. The RES share in transport increases to 73%. The RES share in power generation reaches 86%. RES in electricity consumption account for even 97% given that electricity consumption calculated in line with the procedure for the calculation of the overall RES share excludes losses related to pump storage and hydrogen storage of electricity, the latter being necessary to accommodate all the available RES electricity in particular at times when electricity demand is lower than RES generation.

The second highest RES contribution (58%) materialises in the Low nuclear scenario. The RES share is also rather high under strong energy efficiency policies (57%).

The High RES scenario is the most challenging scenario regarding the restructuring of the energy system including major investments in power generation with RES capacity in 2050 reaching over 1900 GW, which is more than 8 times the current RES capacity and also more than twice today's total generation capacity (including nuclear, all fossil fuels and RES) (for more details see under power generation)

Nuclear

There is also a rather wide range with regard to the contribution of nuclear towards decarbonisation. The nuclear share is highest in the scenario that models the delayed availability of CCS (Scenario 4), given in particular issues arising with transport and storage of CO2 and has no additional policies on renewables and energy efficiency giving rise to an 18% share for nuclear in primary energy demand in 2050, which is 4 percentage points more than is projected under Current Policy Initiatives.

Least use of the nuclear option is made in the Low Nuclear Scenario (Scenario 6), which mirrors a hypothetical Europe-wide sceptical approach to nuclear deployment and investment. This scenario has still a nuclear share in primary energy of 3% in 2050 for reaching 85% CO2 reduction in 2050 similar to all the other decarbonisation scenarios.

The Diversified supply technology scenario (the other scenario, in which technologies compete on their economic merits alone) for reaching decarbonisation has a nuclear share in 2050 of 16% despite of nuclear phase-out in some Member States, which is still slightly higher than the current share. The High RES scenario would leave only little room for nuclear, bringing its share down to 4% in primary energy supply.

CCS

The energy contribution of CCS towards decarbonisation is contingent upon the level of fossil fuel consumption[5] in sufficiently large units to justify economically the deployment of this technology. Hence the CCS share in e.g. gross electricity generation is limited by the degree of energy efficiency and decentralisation of energy supply as well as by the level of RES and nuclear penetration.

The highest share of CCS materialises in the Low Nuclear scenario (scenario 6). This case gives rise to a 32% share of CCS in gross electricity generation in 2050. CCS can substitute for nuclear in the case that this option was available only to a very limited extent. The CCS share would be particularly small in a scenario, in which almost all power generation stems from RES, i.e. Scenario 3, in which the CCS share drops to a mere 7%. The other scenarios have around 19-24% CCS share in gross electricity generation in 2050, with the lower end of the range stemming from delays in CCS technology introduction (mainly linked to storage issues).

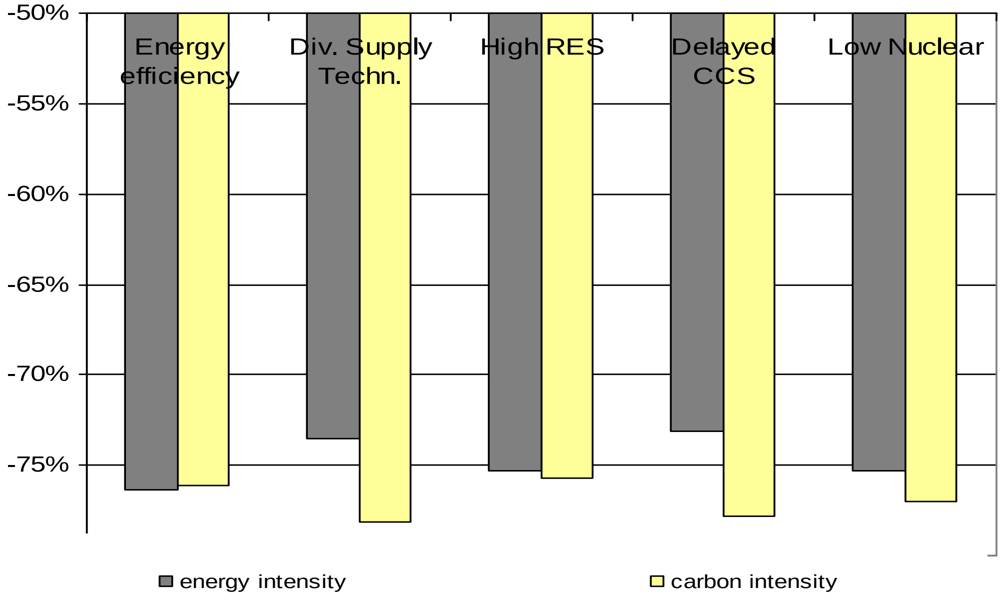
Decarbonisation requires substantial progress on both energy intensity and carbon intensity

The 4 decarbonisation dimensions, explored in 5 decarbonisation scenarios, can also be expressed in terms of energy and carbon intensity. Energy efficiency reduces energy intensity (energy consumption divided by GDP) while the other three options (RES, nuclear and RES) impact overwhelmingly on carbon intensity (CO2 divided by energy consumption). Substantial progress needs to be made on both indicators- energy and carbon intensity –

[5] The discussion here does not deal with CCS used for mitigation of industrial process emissions that do not stem from fossil fuel burning. These considerations exclude also potential removal of CO2 from the atmosphere through fitting CCS to biomass power plants, in which case the atmospheric removal of CO2 during plant growth is not undone by later emissions of CO2 from burning the biomass, with the CO2 from biomass burning being stored instead.

which are to some degree substitutes for each other. The more successful policies to reduce energy consumption are the less needs to be done on fuel switching towards zero/low carbon energy sources, and vice versa[6] (see Figure 19). The five decarbonisation scenarios show substantial improvements in energy intensity which sinks 67%-71% compared with 2005 and 73%-76% compared with the higher 1990 level in terms of energy intensity (1990 had lower energy consumption, but also much lower GDP). Fuel switching continues in the decarbonisation scenarios up to 2050 and carbon intensity would improve substantially falling 76%-78% from 1990 (73%-75% from 2005).

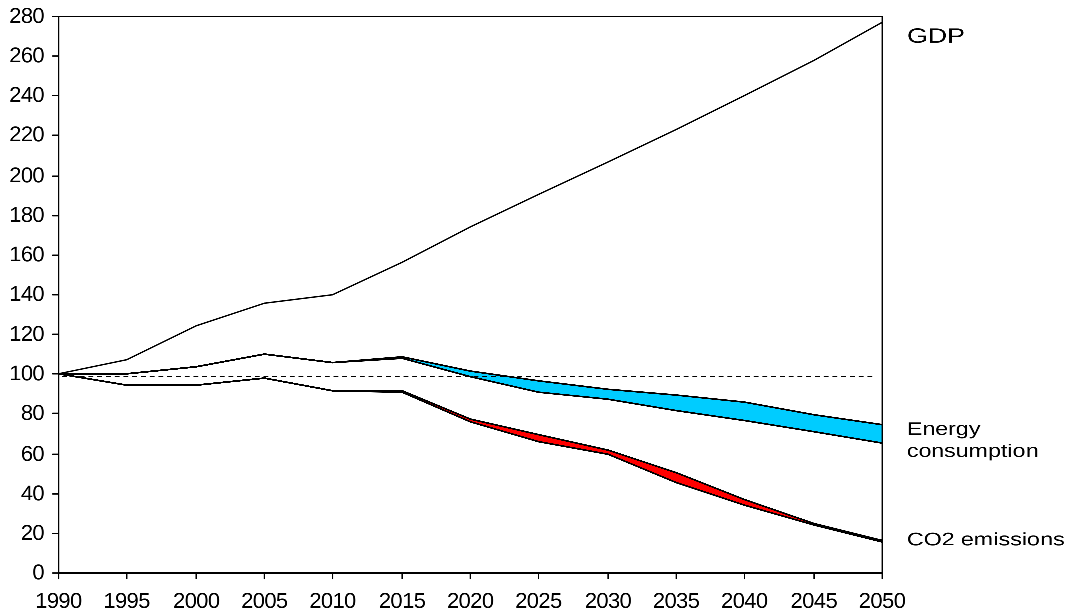
Figure 19: Decarbonisation scenarios: Improvements in carbon and energy intensities (reductions from 1990)



With ongoing economic growth, decarbonisation poses a formidable challenge given that meeting higher demand for energy services (heating and cooling, lighting, cooking, process energy, mobility, communication, etc) is part of increasing welfare. Upward pressure on energy consumption and CO2 emissions from economic growth is substantial given that GDP might increase almost threefold between 1990 and 2050 (see figure 20). The 80% GHG reductions objective by 2050 will however require deep cuts into energy related CO2 emissions, which in turn require energy consumption to decrease substantially as well.

Figure 20: Decarbonisation scenarios: development of GDP, primary energy consumption and energy related CO2 emissions: 1990 = 100

[6] In this respect, carbon intensity is a summary indicator for the fuel mix, while energy intensity captures the efficiency of energy consumption and the composition of economic activity (e.g. share of services versus (heavy) industry).



2.2 Energy consumption and supply structure

Primary energy consumption is significantly lower in all decarbonisation scenarios as compared to the Reference scenario. This is also true for the Current Policy Initiatives scenario that shows 6 and 8% lower demand in 2030 and 2050, respectively than in the Reference scenario reflecting effects of energy efficiency measures in the Energy Efficiency Plan. The biggest decline of primary energy consumption comes in Energy Efficiency scenario (-16% in 2030 and -38% in 2050) showing effects of stringent energy efficiency policies and smart grid deployment. Compared with the actual outcome for 2005, primary energy consumption shrinks by 41%. The decrease in energy consumption compared with Reference for the decarbonisation scenarios spans a range from 11% - 16% in 2030 and from 30% to 38% in 2050. Energy efficiency is therefore an essential building block in all decarbonisation scenarios.

Table 21: Total Primary energy consumption, changes compared to the Reference scenario

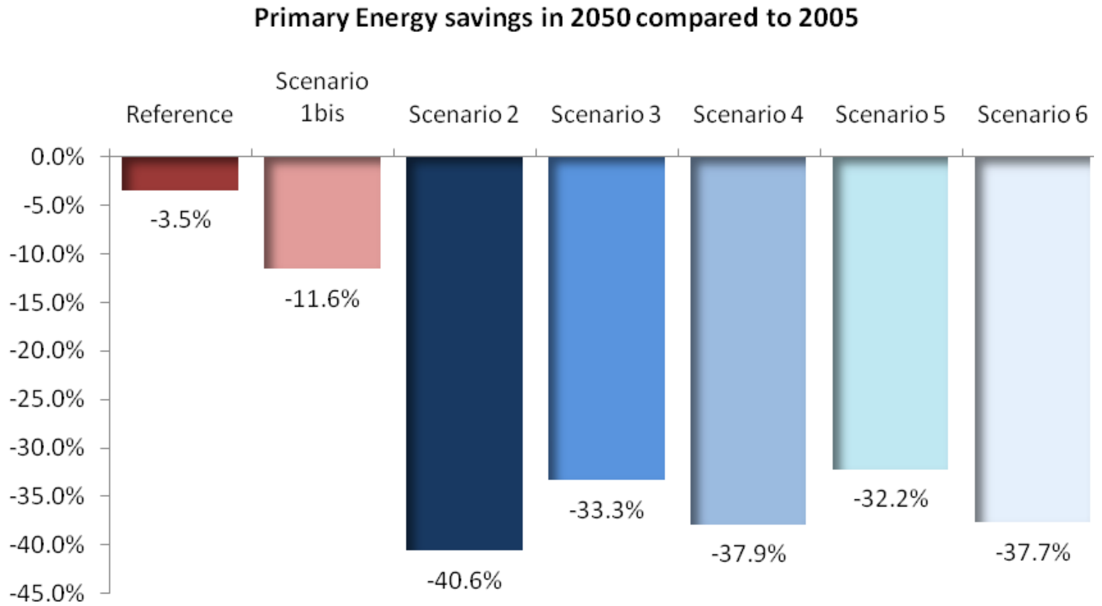
(Mtoe)	2020	2030	2050
Reference	**1790**	**1729**	**1763**
Current policy Initiatives	1700	1629	1615
% difference to Reference	*-5.0%*	*-5.8%*	*-8.4%*
Energy efficiency	1644	1452	1084
% difference to Reference	*-8.1%*	*-16.0%*	*-38.5%*
Diversified supply technologies	1681	1534	1217
% difference to Reference	*-6.1%*	*-11.3%*	*-31.0%*
High RES	1679	1510	1134
% difference to Reference	*-6.2%*	*-12.7%*	*-35.7%*
Delayed CCS	1682	1532	1238
% difference to Reference	*-6.1%*	*-11.4%*	*-29.8%*
Low nuclear	1687	1489	1137
% difference to Reference	*-5.8%*	*-13.9%*	*-35.5%*

It is important to note that these levels of reduced primary energy demand do not come from reduced activity levels (which remains the same across all scenarios). Instead they are mainly the result of technological changes on the demand and also supply side: from more efficient buildings, appliances, heating systems and vehicles and from electrification in transport and heating, which combines very efficient demand side technologies (plug-in hybrids, electric vehicles and heat pumps) with a largely decarbonised power sector. Some changes related especially to fuel switching also contribute to reducing primary energy demand, such as switching from lignite or nuclear power generation to gas or wind based electricity production, which is associated with higher conversion efficiencies. In addition, behavioural change, triggered by e.g. changes in prices, information, energy saving obligations, etc, contributes to better energy efficiency.

Energy intensity of GDP (primary energy divided by GDP) reduces by 53% between 2005 and 2050 in the Reference scenario; the CPI scenario scores significantly better by improving energy intensity 57%. Energy intensity diminishes further in all decarbonisation scenarios: by at least 67% in the delayed CCS scenario. It improves 70% in the high RES and the low nuclear scenarios and even 71% in the energy efficiency scenario. Under decarbonisation, a unit of GDP in 2050 requires only one third of the energy needed today (or slightly less under e.g. a strong energy efficiency focus). By 2030, energy intensity would improve around 45% from current levels under decarbonisation, while this improvement would amount to some 40% under current policies.

Absolute energy savings, not considering the doubling of GDP between now and 2050, show still impressing numbers. Compared with the recent peak in energy consumption in 2005/6, the energy efficiency scenario depicts 41% less energy consumption, which means a substantial energy saving with respect to the levels reached just before the economic crisis.

Figure 21: Primary energy savings in 2050 compared to 2005

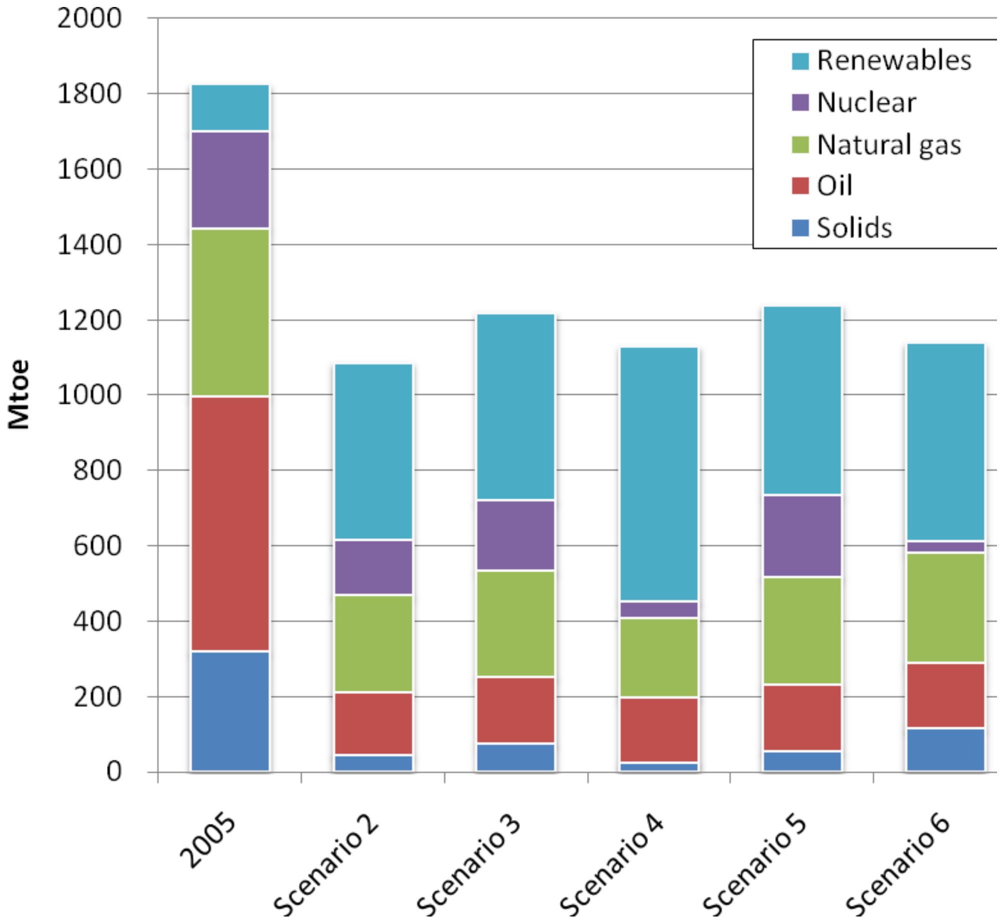


It is important to note that these levels of reduced primary energy demand do not come from reduced GDP or sectoral production levels (which remain the same in all scenarios). Instead they are mainly the result of technological changes on the demand and supply side, coming from more efficient buildings, appliances, heating systems and vehicles and from electrification in transport and heating. All decarbonisation scenarios over-achieve the 20% energy saving objective in the decade 2020-2030.

The scenarios are based on model assumptions, which are consistent with the input for the 2050 Low Carbon Economy Roadmap. Recognising the magnitude of the decarbonisation challenge, which implies a reversal of a secular trend towards ever increasing energy consumption, this Energy Roadmap has adopted a rather conservative approach as regards the effectiveness of policy instruments in terms of behavioural change. However, the Roadmap results should not be read as implying that the 20% energy efficiency target for 2020 cannot be reached effectively. Greater effects of the Energy Efficiency Plan are possible if the Energy Efficiency Directive is adopted swiftly and completely, followed up by vigorous implementation and marked change in the energy consumption decision making of individuals and companies.[7]

Not only the amount, but also the composition of energy mix would differ significantly in a decarbonised energy system. Figure 22 shows total energy consumption as well as its composition in terms of fuels in 2050 for the various scenarios.

Figure 22: Total Primary Energy in 2050, by fuel



[7] In modelling terms this means a significant lowering of the discount rate used in energy consumption decision making of hundreds of millions of consumers.

Low and zero carbon content energy sources are strongly encouraged by going the various decarbonisation routes, each of them focusing on different aspects. This has different repercussions on the fuel mix. Energy efficiency encourages primary sources that can be used with small losses (e.g. many renewables or gas) and electricity at the level of final demand. CCS strategies affect the fuel mix by largely neutralising the high carbon content of fossil fuels, notably coal and lignite, through removal of the associated emissions. RES and nuclear routes are directly targeting the fuel mix. The modelling leads to rather wide ranges for primary energy sources with these fuel mixes in the decarbonisation cases all satisfying the decarbonisation requirement by 2050. Moreover, the development of all the fuel mixes under decarbonisation give rise to the same cumulative GHG emissions from 2011 to 2050.

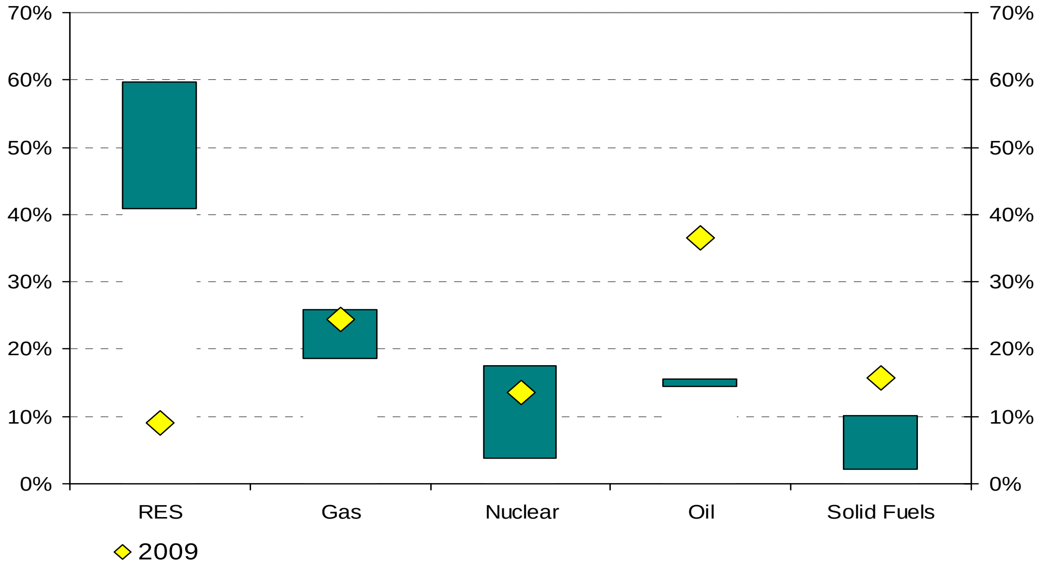
Table 22: Share of fuels in primary energy consumption in %

		Reference scenario		Current Policy Initiatives		Decarbonisation scenarios	
	2005	2030	2050	2030	2050	2030	2050
Solids	17.5	12.4	11.4	12.0	9.4	7.2-9.1	2.1-10.2
Oil	37.1	32.8	31.8	34.1	32.0	33.4-34.4	14.1-15.5
Gas	24.4	22.2	20.4	22.7	21.9	23.4-25.2	18.6-25.9
Nuclear	14.1	14.3	16.7	12.1	13.5	8.4-13.2	2.6-17.5
Renewables	6.8	18.4	19.9	19.3	23.3	21.9-25.6	40.8-59.6

Renewables increase their share significantly under adopted policies and would substantially rise in all decarbonisation scenarios to reach at least 22% of primary energy consumption by 2030 and 41% by 2050. The RES share is comparably low in those scenarios, in which nuclear plays a rather strong role (scenarios 4 and 5). The RES share is highest in High RES scenario reaching 60% in primary energy by 2050. It is also pretty high (44% and 46% in primary energy in 2050) in the Energy Efficiency and Low nuclear scenarios, respectively.

The RES share is higher when calculated in gross final energy consumption (indicator used for the 20% RES target). It represents at least 28% (2030) and 55% (2050) in all decarbonisation scenarios and rises up to 75% in 2050 in the High RES scenario.

Figure 23: Range of Fuel Shares in Primary Energy in 2050 compared with 2009 outcome



Nuclear developments have been significantly affected by the policy reaction in Member States after the nuclear accident in Fukushima (abandoning substantial nuclear plans in Italy, revision of nuclear policy in Germany). These reactions and the forthcoming nuclear stress tests have been reflected in the modelling assumptions for the Current Policy Initiatives scenario (1bis). The downward effects for nuclear penetration in CPI are also present in the decarbonisation scenarios, since the modelling of these cases also included the recent policy adjustments on nuclear.

The share of nuclear varies depending on assumptions taken. In the scenario without new nuclear investment (except for plants under construction) and extension of lifetime only in this and the next decade, the nuclear share declines gradually to 3% by 2050. In the most ambitious nuclear scenario - Delayed CCS, the share rises to 18%[8].

The share of gas under Current Policy Initiatives is higher than in the Reference scenario reflecting abandon of the nuclear programme in Italy, no new nuclear power plants in Belgium and higher costs for new plants and retrofitting. The gas share increases slightly to 26% in 2050 in the Low nuclear scenario where the CCS share in power generation is around 32%.

8 This share is considerably lower than in decarbonisation scenarios of DG CLIMA. There are three main explanations:

1. Decarbonisation scenarios and Current Policy Initiatives scenario are based on revised assumptions on nuclear (abandon of nuclear programme in Italy, no new nuclear plants in Belgium and upwards revision of costs for nuclear power plants).
2. Electricity demand is lower than in the Low Carbon Economy Roadmap Scenarios due to stringent energy efficiency measures.
3. Revised assumptions on the potential of electricity in transport compared to the DG CLIMA decarbonisation scenarios, following more closely the scenarios developed in the White Paper on Transport leading to lower utilisation rate of nuclear power plants than in the Low Carbon Economy Roadmap Scenarios. Electric vehicles flatten electricity demand and thus incentivise base load power generation.

The oil share declines only slightly until 2030 (and even 2040) due to high dependency of transport on oil based fuels. However, the decline is significant in the last decade 2040-2050 where oil in transport is replaced by biofuels and electric vehicles. The oil share drops to around 15% in 2050 when following any of the examined main directions towards decarbonisation.

The share of solid fuels continues its long standing downward trend already under Reference and CPI developments. Under substantial decarbonisation the solids share shrinks further to reach levels as low as 2% in the High RES scenario in 2050 and only 4% and 5% under Energy efficiency and Delayed CCS, respectively. The solids share would remain rather high only in the Low nuclear scenario (10% in 2050) with a high CCS contribution which allows a continued use of solids in a decarbonisation context.

Final energy demand declines similarly to primary energy demand. Current Policy Scenario shows around 5% decrease (in 2020-2050) compared to the Reference scenario. In the Energy Efficiency scenario the reduction on Reference in final energy demand is -14% in 2030 and -40% in 2050. The decrease in the decarbonisation scenarios is at least -8% in 2030 and -34% in 2050. Compared with actual 2005 outcome, final energy consumption decreases in 2050 by 37% in the High Energy Efficiency scenario and by around 32% in all the other decarbonisation scenarios.

Sectors showing higher reductions than the average are residential, tertiary and generally also transport.

Table 23: Final energy demand, changes compared to the Reference scenario

	Reference scenario			Current Policy Initiatives			Energy efficiency			Diversified supply technologies		
	2020	2030	2050	2020	2030	2050	2020	2030	2050	2020	2030	2050
Final Energy Demand (Mtoe)	**1227**	**1187**	**1221**	**-6%**	**-4%**	**-5%**	**-9%**	**-14%**	**-40%**	**-7%**	**-9%**	**-34%**
Industry	330	333	369	-4%	-5%	-5%	-4%	-5%	-30%	-4%	-5%	-26%
Residential	318	299	288	-9%	-6%	-4%	-13%	-20%	-43%	-9%	-12%	-35%
Tertiary	181	174	181	-8%	-5%	-7%	-13%	-25%	-53%	-8%	-15%	-42%
Transport	398	382	383	-4%	-2%	-6%	-7%	-12%	-40%	-7%	-9%	-38%

	High RES			Delayed CCS			Low nuclear		
	2020	2030	2050	2020	2030	2050	2020	2030	2050
Final Energy Demand (Mtoe)	**-7%**	**-8%**	**-34%**	**-7%**	**-10%**	**-35%**	**-6%**	**-10%**	**-35%**
Industry	-4%	-4%	-25%	-4%	-5%	-26%	-3%	-6%	-26%
Residential	-9%	-9%	-34%	-9%	-12%	-35%	-9%	-13%	-36%
Tertiary	-8%	-13%	-44%	-8%	-16%	-42%	-7%	-17%	-43%

Transport	-7%	-8%	-38%	-7%	-9%	-39%	-7%	-9%	-39%

There is a lot of structural change in the fuel composition of final energy demand. Given its high efficiency and emission free nature at use, electricity makes major inroads already under current policies (increase by 9 pp between 2005 and 2050 in CPI).

The electricity share soars further in decarbonisation scenarios reaching 36% - 39% in 2050, reflecting also its important role in decarbonising further final demand sectors such as heating and services and in particular transport. The electricity share would almost double by 2050. The crucial issue for any decarbonisation strategy is therefore the full decarbonisation of power generation (see below).

Table 24: Final energy consumption by fuel in various scenarios

		Reference/CPI		Decarbonisation scenarios	
	2005	2030	2050	2030	2050
Electricity	20,2%	24,5% - 25,1%	29,1% - 29,4%	25,2% - 26,0%	36,1% - 38,7%
RES (direct)	4,9%	9,1% - 9,2%	9,0% - 9,4%	8,5% - 10,5%	23,8% - 30,0%
Oil	42,2%	36,1% - 36,8%	35,0% - 35,5%	33,2% - 34,6%	14,9% - 15,6%
Gas	24,2%	18,7% - 19,1%	16,1% - 16,6%	19,4% - 20,0%	11,9% - 12,7%
Heat	3,8%	7,3% - 7,5%	8,2% - 8,6%	7,1% - 8,0%	6,7% - 10,0%
Solid fuels	4,6%	3,2% - 3,3%	2,9% - 3,1%	2,5% - 3,0%	0,3% - 0,4%

Also RES make major inroads under current policies including the 2009 RES Directive. The direct use of RES in final demand (i.e. not counting here the RES input to power and distributed heat generation) rises strongly to 2030 coming close to a doubling of the share. However, without additional policy push beyond the current RES/climate change measures, this RES share could be stagnant. On the contrary, in decarbonisation scenarios the share of directly used RES (e.g. biomass, solar thermal) would go up to 24% in 2050 in almost all decarbonisation cases, except for the high RES scenario, where this share reaches even 30%.

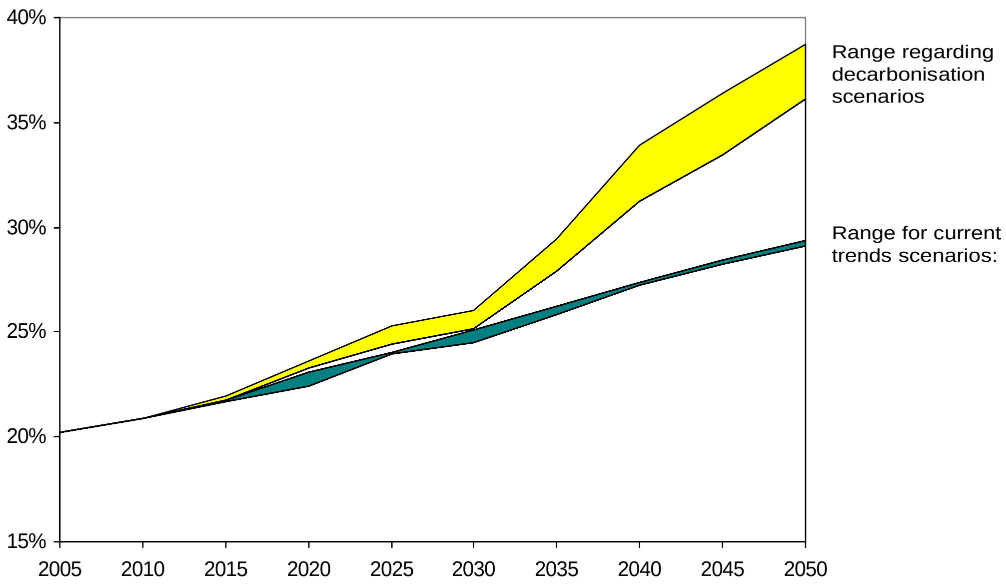
Oil has been dominating final energy for many years and might continue doing so until 2030 even in the decarbonisation scenarios, when is would still account for one third of energy deliveries to final consumers. The big changes come after 2030 when more and more parts of final energy consumption based on oil, especially in transport, are replaced by electricity (e.g. electric and plug in hybrid vehicles, heat pumps). The oil share in 2050 would drop to around 15%.

The gas share has been declining in recent years and would be lower than today under both current policies and decarbonisation in 2030, when gas would account for not more than a fifth in final demand. The gas share after 2030 would be decreasing further in particular in decarbonisation scenarios, which is due to the greater role of electricity in both heating and for providing energy in productive sectors.

Distributed heat would deliver 7-8% of final energy demand in 2030 under both current policies and decarbonisation, raising its share substantially from current levels. The heat share in 2050 would be highest (10%) in the Low nuclear scenario where high electricity production is ensured by CCS equipped generation from gas and solids, often in a CHP mode.

Solid fuels become rather obsolete in final energy demand under current policies (falling to around 3% in 2030-2050). The decline of the solids share reflects higher use of electricity and gas in heating and industry. Solid fuels become marginal under decarbonisation, especially by 2050, when most solids base processes have been replaced by electricity or other fuels. The solid fuel share in 2050 would shrink to 0.3-0.4%.

Figure 24: Shares of Electricity in Current Trend and Decarbonisation Scenarios



2.3 Power generation

Electricity demand increases in all scenarios compared to 2005 levels, following greater penetration of electricity using appliances, heating and propulsion systems. The increased use of electric devices is partly compensated by the increased energy efficiency of electric appliances as well as increased thermal integrity in the residential and service sectors and more rational use of energy in all sectors, but overall the effect from emerging new electricity uses at large scale for heating and transport is decisive. The development of electricity consumption varies between sectors.

Transport electricity demand increases strongest. The increase of electricity use in transport is due to the electrification of road transport, in particular private cars, which can either be plug-in hybrid or pure electric vehicle; almost 80% of private passenger transport activity is carried out with these kinds of vehicles by 2050. Despite substantial progress regarding energy efficiency of appliances and for efficient heating systems, such as heat pumps, household electricity demand in 2050 under decarbonisation exceeds the current level given the additional deployment of electricity in heating and cooling.

Electricity demand in the other sectors decreases or remains flat under decarbonisation. Electricity demand in services/agriculture diminishes in all decarbonisation scenarios as a result of strong energy efficiency policies, although there is a substitution from other energy carriers to more efficient electric devices e.g. heat pumps. . Industrial electricity demand remains broadly at the current level by 2050 under decarbonisation.

Table 25: Electricity final energy demand

	2005	2050		
		Reference	Scenario 1bis	Scenario 2
Final energy demand (in TWH)	2762	4130	3951	3203
Industry	1134	1504	1426	1109
Households	795	1343	1230	913
Tertiary	759	1184	1041	518
Transport	74	100	255	663
	2050			
	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Final energy demand (in TWh)	3618	3377	3585	3552
Industry	1211	1169	1201	1191
Households	1026	938	1019	1013
Tertiary	707	605	696	677
Transport	675	664	669	671

Power generation: level and structure by fuel

Given the assumed limited electricity import possibilities from third countries, the increased electricity demand will have to be generated nearly exclusively within the EU. Moreover, electricity production has to cover also power plant own consumption (e.g. for desulphurisation), the consumption of the other energy producing sectors (energy branch) as well as transmission and distribution losses. Furthermore, additional electricity generation is appropriate under strong decarbonisation objectives to produce hydrogen mixed in low and medium pressure gas networks (bringing down emission factors in final demand) and for producing hydrogen, which is used for balancing in the case of high RES scenarios. Therefore, similar to electricity demand there is a strong increase from current levels for power generation in all scenarios. Under decarbonisation, power generation will be lower in 2050 compared with Reference and CPI scenarios. The highest electricity generation level in 2050 among the decarbonisation cases comes about in case of CO2 reduction focussing particularly strongly on RES.

The structure of power generation changes substantially between the scenarios. The Reference scenario and the Current Policy Initiatives scenario show renewable shares in 2050 reaching 40 and 49% respectively and fossil fuels still having a share of 33 and 31% respectively. Among the decarbonisation scenarios, only the Low nuclear scenario has a share of fossil fuels above 30%, as it makes substantial use of CCS. In the other scenarios the fossil fuel share lies below 25% and is particularly low in High RES scenario, where fossil fuels account for under 10% of electricity generation.

Under decarbonisation, power generation in 2050 is based on renewables for at around 60%-65%, except for the high RES case, in which this share is much higher. Wind alone accounts for about one third of power generation in most decarbonisation scenarios. In the high RES case, the wind share reaches even close to 50% in 2050. The nuclear share falls from the present level in all decarbonisation scenarios. This share is highest in 2050 under delayed CCS, in which case it is around 20%. On the contrary, in the low nuclear scenario, nuclear would account for just 2.5% of power generation.

Table 26: Power generation

		2005	2050		
			Reference	Scenario 1bis	Scenario 2
Electricity generation	TWh	**3274**	**4931**	**4620**	**4281**
Nuclear energy	Shares (%)	30.5	26.4	20.6	14.2
Renewables		14.3	40.3	48.8	64.2
Hydro		*9.4*	*7.6*	*8.5*	*9.2*
Wind		*2.2*	*20.1*	*24.7*	*33.2*
Solar, tidal etc.		*0.0*	*5.1*	*7.0*	*10.6*
Biomass & waste		*2.6*	*7.3*	*8.4*	*10.9*
Geothermal heat		*0.2*	*0.2*	*0.2*	*0.3*
Fossil fuels		55.2	33.3	30.6	21.6
Coal and lignite		*30.0*	*15.2*	*11.1*	*4.8*
Petroleum products		*4.1*	*2.2*	*2.1*	*0.0*
Natural gas		*20.3*	*15.1*	*16.7*	*16.7*
Coke & blast-furnace gasses		*0.9*	*0.7*	*0.7*	*0.0*
Other fuels (hydrogen, methanol)		0.0	0.0	0.0	0.0
		2050			
		Scenario 3	Scenario 4	Scenario 5	Scenario 6
Electricity generation	TWh	**4912**	**5141**	**4872**	**4853**
Nuclear energy	Shares (%)	16.1	3.5	19.2	2.5
Renewables		59.1	83.1	60.7	64.8
Hydro		*8.0*	*7.7*	*8.1*	*8.1*
Wind		*31.6*	*48.7*	*32.4*	*35.6*
Solar, tidal etc.		*9.9*	*16.4*	*9.9*	*10.8*
Biomass & waste		*9.3*	*9.6*	*9.9*	*9.8*
Geothermal heat		*0.3*	*0.6*	*0.4*	*0.4*
Fossil fuels		24.8	9.6	20.1	32.7
Coal and lignite		*8.1*	*2.1*	*5.1*	*13.1*
Petroleum products		*0.0*	*0.0*	*0.0*	*0.1*
Natural gas		*16.6*	*7.5*	*14.9*	*19.5*
Coke & blast-furnace gasses		*0.0*	*0.0*	*0.0*	*0.0*
Other fuels (hydrogen, methanol)		0.0	3.9	0.0	0.0

NB: power generation is presented in the most comprehensive way in this table involving in a sense some "double counting" in the denominator of shares for the high RES scenario: first electricity generation from RES is counted including those parts of RES based generation that, in case supply exceeds demand, are transformed into hydrogen for later use by producing electricity for a second time from these original renewables sources. This specific representation for showing also the magnitude of hydrogen based RES electricity storage (4% in

2050) leads to total electricity generation numbers that are in a sense inflated, which in turn gives rise to lower RES share numbers in this specific representation that counts production from RES once as such and secondly under hydrogen based generation (shown separately) for the part that is not lost in transformations into hydrogen and back from hydrogen to electricity.

Power plant investments by fuel type (e.g. RES, nuclear, fossils with CCS, fossil without CCS)

The installed capacity increases in all scenarios compared to the Reference scenario due to the additional balancing and power reserve capacities needed for the variable RES which increase in all scenarios. The scenario with the least increase is Energy Efficiency scenario which requires the least amount of electricity and therefore also the least amount of installed capacity. All scenarios still have fossil fuel fired power plants as installed capacity, which are used mainly as back-up.
The share of CCS capacity in thermal power plants for the decarbonisation scenarios ranges from 48% in Low nuclear scenario to 12% in High RES scenario. The share in the other scenarios is between 35 and 44%.

Table 27: Installed power capacity

		2005	2050		
			Reference	Scenario 1bis	Scenario 2
Net Installed Power Capacity	GWe	**715**	**1454**	**1502**	**1473**
Nuclear energy		134	161	117	79
Renewables (without biomass/geothermal)		147	681	784	1012
Hydro (pumping excluded)		*105*	*121*	*122*	*125*
Wind power		*41*	*382*	*432*	*548*
Wind on-shore		*40*	*262*	*291*	*370*
Wind off-shore		1	120	140	177
Solar		*2*	*171*	*224*	*330*
Other renewables (tidal etc.)		*0*	*6*	*7*	*9*
Thermal power		*434*	*613*	*601*	*382*
Solids fired		*187*	*131*	*104*	*70*
Oil fired		62	168	38	15
Gas fired		167	226	366	187
Biomass-waste fired		*18*	*87*	*92*	*108*
Hydrogen plants		*0*	*0*	*0*	*0*
Geothermal heat		*1*	*1*	*1*	*2*
		2050			
		Scenario 3	Scenario 4	Scenario 5	Scenario 6
Net Installed Power Capacity	GWe	**1621**	**2219**	**1639**	**1721**
Nuclear energy		102	41	127	16
Renewable (without biomass/geothermal)		1081	1749	1093	1193
Hydro (pumping excluded)		*126*	*131*	*126*	*127*
Wind power		*595*	*984*	*609*	*674*

Wind on-shore		*398*	*612*	*408*	*452*
Wind off-shore		197	373	200	222
Solar		*351*	*603*	*348*	*381*
Other renewables (tidal etc.)		*10*	*30*	*10*	*11*
Thermal power		*439*	*429*	*419*	*513*
Solids fired		*94*	*62*	*73*	*125*
Oil fired		19	19	18	18
Gas fired		218	182	210	255
Biomass-waste fired		*106*	*163*	*115*	*112*
Hydrogen plants *		*0*	*0*	*0*	*0*
Geothermal heat		*2*	*4*	*2*	*2*

		2005	2050		
			Reference	Scenario 1bis	Scenario 2
Total CCS capacity	GWe	0	**101**	**39**	**149**
Solids	GWe	0	*64*	*33*	*28*
Oil	GWe	0	*0*	*0*	*0*
Gas	GWe	0	*37*	*6*	*121*
		2050			
		Scenario 3	Scenario 4	Scenario 5	Scenario 6
Total CCS capacity	GWe	**193**	**53**	**148**	**248**
Solids	GWe	*50*	*18*	*30*	*79*
Oil	GWe	*0*	*0*	*0*	*0*
Gas	GWe	*142*	*34*	*118*	*169*

* Hydrogen capacity in the above table refers only to plant technologies dedicated to specific hydrogen use, such as fuel cells. Capacity for generating electricity from hydrogen, serving only the purpose of storing RES based electricity that was previously produced at times when electricity supply exceeded demand, is accounted for under gas fired capacity, given that hydrogen would be burnt is such types of plants, including as a mixture with natural gas.

The high RES scenario is a particularly challenging scenario regarding the restructuring of the energy system involved; RES policy related challenges in this scenario include the following:

- Huge investments in RES power capacity need to be ensured with wind capacity alone reaching over 980 GW in 2050, this is 20% more than today's (2010) total power generation capacity (including nuclear, fossil fuels and all RES); similarly, solar capacity would need to soar to 600 GW, which amounts to almost three quarters of our present total generation capacity; all RES power generation capacity (Renewables + biomass/waste + geothermal in table 27) would need to increase to over 1900 GW, which is more than 8 times the current RES capacity and also more than twice today's total generation capacity.
- It might be a challenge to ensure the raw material needed for RES technologies and there may be upward pressure on e.g. steel prices, which could be a challenge to such a development (not modelled with the energy model); other logistic challenges would

relate to ensuring the maritime equipment to install and maintain the off-shore wind capacity that rises from just close to 5 GW today to over 370 GW in 2050;

- In order to accommodate RES production from remote sites with respect to consumption centres and to take advantage of the cost differences across Member States for cost-effectiveness reasons, the grid needs to be extended substantially and also smartened to deal with variable feed in from many dispersed sources (e.g. solar PV); the scenario analysis identified needs for grid extension beyond 2020 under a decarbonisation agenda and in addition a set of additional DC links (electricity highways) needed to accommodate a very high RES contribution to electricity supply (see attachment 2 to this Annex);
- Another challenge relates to the skilled workforce required, the lack of which can lead to a stalled development unless a major RES related education and training strategy is pursued taking account of ageing EU population over the next decades, which is even shrinking after 2035. Skilled workforce will also be needed for the construction of expanded, smart grids, which will also be necessary for the penetration of other low carbon technologies.
- In addition to economic, logistical, resource security and manpower challenges, there is the acceptance issue for new transmission lines and perhaps also regarding the substantial expansion of (on-shore) RES installations;

It will also be challenging in the other decarbonisation scenarios to ensure the required RES capacity in 2050 and to accommodate it by the grid. The Energy Efficiency scenario poses the least challenge given the lowest electricity demand, but nevertheless, RES power generation capacity would need to soar to 5 times the current level, exceeding today's total electricity generation capacity (nuclear, fossil fuel and RES combined) by more than a third. On the other hand, increased energy efficiency and decentralised RES might require more sophisticated solutions for distribution level.

Other scenarios pose also substantial challenges throughout the transition. For example, higher nuclear deployment in the delayed CCS scenario leads to more requirements for nuclear fuel and more nuclear waste that needs to be safely transported and stored. Electrification of passenger transport involves many changes in car production and infrastructure provision. A smooth transition from a petrol/diesel to an electricity based system for mainly urban transport requires a lot of logistical changes.

Widespread penetration of CCS will require dedicated CO2 transport grids that need to be financed, constructed and accepted. Acceptance challenges could be particularly pronounced for nuclear and CO2 storage. As carbon capture, transport and storage require significant quantities of electricity that need to be generated in addition to electricity for final use, there would be higher input demand also for fossil fuels. This effect would be particularly pronounced if global decarbonisation includes an important contribution from CCS for energy consumption and also for abatement of industrial process emissions. This could exert upward pressure on the level of world fossil fuel prices.

All scenarios involve substantial changes in production, transformation, smart transmission/distribution and consumption patters for energy, requiring a skilled workforce against the background of ageing population. Enhancement of the European capacity for innovation, appropriate RTD as well as education and training will be instrumental for a cost-effective transition to a low carbon economy that fosters competitiveness and security of supply.

Decarbonisation requires also considerable capacity for CCS, except for the high RES scenario. The other scenarios involve around 150 GW – 250 GW CCS capacity in 2050, with the upper end materialising in Low nuclear scenario, which is the case with the greatest use of CCS for power generation (32% share

In Table 28 the capacity investment per decade for the scenarios can be seen; as can be observed the highest investments take place in RES in all scenarios. As can be seen no new investment is undertaken in nuclear in Low nuclear scenario after 2030; only Delayed CCS sees higher nuclear investment than in the Reference scenario for the last two decades of the projection period. Investment continues in thermal power plants throughout the projection period in all scenarios; it is lowest in High RES and Energy efficiency scenarios. These investment numbers include lifetime extensions of existing plants, refurbishments and replacement investments on existing sites, which is particularly relevant for nuclear. These investment numbers must not be confused with additional new plants of e.g. nuclear.

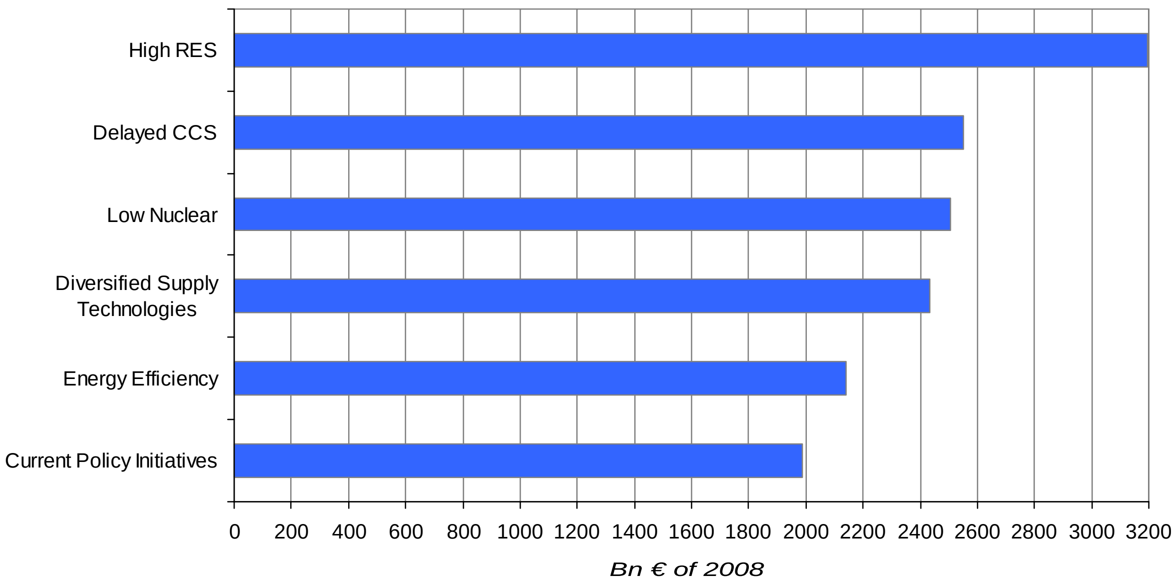
Table 28: Net Power Capacity Investment in GWe per decade

		2011-2020	2021-2030	2031-2040	2041-2050
Reference	Nuclear energy	15	64	46	62
	Renewable energy	192	169	192	259
	Thermal power fossil fuels	100	78	184	183
	of which: CCS	5	6	48	41
	Thermal power RES	37	17	14	24
Scenario 1 bis	Nuclear energy	12	42	41	49
	Renewable energy	187	169	245	309
	Thermal power fossil fuels	101	72	169	198
	of which: CCS	3	0	19	17
	Thermal power RES	38	17	13	29
Scenario 2	Nuclear energy	11	24	34	22
	Renewable energy	204	222	318	436
	Thermal power fossil fuels	86	23	92	92
	of which: CCS	3	0	56	90
	Thermal power RES	38	19	27	29
Scenario 3	Nuclear energy	12	46	36	35
	Renewable energy	214	250	348	463
	Thermal power fossil fuels	90	37	130	101
	of which: CCS	3	1	91	98
	Thermal power RES	40	20	27	25
Scenario 4	Nuclear energy	12	30	12	0
	Renewable energy	215	396	588	817
	Thermal power fossil fuels	88	35	66	91
	of which: CCS	3	0	19	30
	Thermal power RES	38	22	55	53

Scenario 5	Nuclear energy	12	47	56	39
	Renewable energy	214	256	354	464
	Thermal power fossil fuels	89	36	79	115
	of which: CCS	3	0	35	110
	Thermal power RES	39	20	37	23
Scenario 6	Nuclear energy	11	4	0	0
	Renewable energy	213	281	385	515
	Thermal power fossil fuels	90	50	163	121
	of which: CCS	3	5	121	118
	Thermal power RES	39	25	26	27

Investment in generation capacity entails substantial cumulative investment expenditure in all scenarios over the period 2011-2050. Cumulative investment expenditure for power generation is most pronounced in the high RES scenario amounting to over 3 trillion € in real terms up to 2050. Among the decarbonisation scenarios cumulative investment expenditure for power generation is lowest in the Energy Efficiency scenario given the marked savings in electricity consumption.

Figure 25: Cumulative investment expenditure in 2011-2050 for power generation (in € of 2008)



These investment expenditure results impact on electricity generation costs in the different scenarios (see below)

Impacts on infrastructure

Infrastructure requirements differ in scenarios. Decarbonisation scenarios require more and more sophisticated infrastructures (mainly electricity lines, smart grids and storage) than Reference and CPI scenarios. High RES scenario necessitates additional DC lines mainly to transport wind electricity from the North Sea to the centre of Europe and more storage. The biggest share of costs relate to the upgrade and improvement of distribution networks including smartening of the grid. Investments needed in transmission lines are much lower and new interconnectors represent only a fraction of these transmission costs.

Table 29: Grid investment costs

(Bn Euro'05)	Grid investment costs			
	2011-2020	2021-2030	2031-2050	2011-2050
Reference	292	316	662	1269
CPI	293	291	774	1357
Energy Efficiency	305	352	861	1518
Diversified supply technologies	337	416	959	1712
High RES	336	536	1323	2195
Delayed CCS	336	420	961	1717
Low nuclear	339	425	1029	1793

Euro'05	Transmission Grid investment (bEUR)				
	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050
Reference	47.9	52.2	53.5	52.0	205.7
CPI	47.1	49.6	64.8	66.6	228.2
Energy Efficiency	49.0	63.1	80.3	80.1	272.5
Diversified supply technologies	52.8	70.2	88.0	86.8	297.8
High RES	52.8	95.5	137.8	134.4	420.4
Delayed CCS	52.7	71.0	88.6	87.6	299.9
Low nuclear	52.9	73.8	95.2	94.8	316.6

Euro'05	Distribution Grid investment (bEUR)				
	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050
Reference	243.7	263.5	280.5	276.0	1063.7
CPI	245.0	239.3	317.6	325.9	1127.8
Energy Efficiency	256.3	289.1	408.4	291.8	1245.5
Diversified supply technologies	284.2	345.9	454.3	329.8	1414.1
High RES	283.5	440.0	619.8	431.5	1774.8
Delayed CCS	283.4	349.4	445.1	339.6	1417.5
Low nuclear	286.4	350.8	472.5	366.5	1476.3

Euro'08	Investments in new electricity interconnectors		
	2006-2020	2021-2030	2031-2050
Reference	13.1	0.3	0.0
CPI	21.9	9.7	0.6
High energy efficiency	21.9	9.7	0.6
Diversified supply technologies	21.9	9.7	0.6
High RES	21.9	21.2	50.8
Delayed CCS	21.9	9.7	0.6
Low nuclear	21.9	9.7	0.6

The model assumes that grid investments, that are prerequisites to the decarbonisation scenarios in this analysis, are undertaken and that costs are fully recovered in electricity prices. The reality might differ from this model situation in a sense that current regulatory regime might be more short to medium term cost minimisation oriented and might not provide sufficient incentives for long-term and innovative investments. There might also be less perfect foresight and lower coordination of investments in generation, transmission and distribution as the model predicts.

Power generation costs

Fixed operational and capital costs for power generation increase over time in all scenarios. The increase in capital costs is more pronounced in decarbonisation scenarios, notably in the High RES case. A substantial RES contribution (high RES scenario) leads to an increase of fixed and capital costs of 155% in 2050 compared with 2005 (81% rise by 2030) due to the additional investment needs in generation, grid, storage and back-up capacities. On the contrary, the increase in variable and fuel costs over time under Reference and CPI developments would be more or less cancelled in the decarbonisation cases. This effect of shifting variable and fuel costs towards capital costs is most pronounced in the High RES scenario. In this decarbonisation case, the substantial RES contribution leads to a decline of variable and fuel costs by 45% below Reference in 2050 and also a decrease by 21% on the 2005 level.

Unit costs of transmission and distribution increase substantially in all decarbonisation scenarios. The High RES case has the greatest increase. Due to the decarbonisation of the power sector in all scenarios in the last two decades of the projection period, the costs related to ETS auction payments decrease substantially.

These effects on cost components allow for a decrease in electricity prices between 2030 and 2050 in all decarbonisation scenarios, except for the High RES scenario. This is in stark contrast to the period up to 2030, in which electricity prices increase due notably to increases in capital cost, grid costs and auctioning payments. The High RES case is an exception from other cases because of the very high investment requirements combined with stronger requirements on the electricity grid extension, which is not fully compensated by savings in fuel and other variable costs.

Therefore the High RES case features the highest electricity prices among the decarbonisation scenarios, as it would not allow for the flattening out of the strong price increase up to 2030 (observed in all scenarios) but continues with major capital intensive changes to the power system.

Table 31: Electricity prices and cost structure [9]

(Euro'08 per MWhe)			Reference		Scenario 1bis		Scenario 2	
	2005		2030	2050	2030	2050	2030	2050
Fixed and capital costs	39.6		56.7	52.4	57.4	54.6	63.4	61.6
Variable and fuel costs	32.0		40.6	46.2	41.1	43.5	34.8	31.2
Tax on fuels and ETS payments	1.0		9.9	5.0	8.6	6.9	5.0	1.3
Grid and sales costs	22.8		25.9	25.8	26.7	28.7	28.6	29.5
Average price of electricity (pre-tax)(*)	95.4		133.2	129.4	133.7	133.6	131.7	123.5
Average price of electricity (After-tax) (*)	109.3		154.8	151.1	156.0	156.9	154.4	146.7
(Euro'08 per MWhe)	Scenario 3		Scenario 4		Scenario 5		Scenario 6	
	2030	2050	2030	2050	2030	2050	2030	2050
Fixed and capital costs	63.3	61.9	71.7	101.0	63.9	65.3	64.3	65.3
Variable and fuel costs	34.6	31.3	31.9	25.3	34.4	31.8	37.1	34.6
Tax on fuels and ETS payments	9.3	0.9	5.6	3.6	9.5	1.6	12.2	1.4
Grid and sales costs	29.1	29.1	31.5	41.2	29.3	29.9	30.7	31.9
Average price of electricity (pre-tax) (*)	136.4	123.2	140.7	171.0	137.1	128.6	144.3	133.2
Average price of electricity (After-tax) (*)	159.6	146.2	164.4	198.9	160.4	151.9	168.2	157.2

(*): Average price over all consumer types, including final consumers and energy branch

It is important to note that, as explained in the assumptions part, the PRIMES model makes sure that the full costs of electricity production and distribution are recovered through electricity prices. Both marginal costs and the appropriate portion of fixed capital and operation costs are allocated to the various sectors according to the Ramsey Boiteux methodology taking into account price elasticities in the allocation of fixed costs. This procedure is necessary to ensure a sustainable modelling solution because in internally consistent scenarios electricity sector investments need to be financed by the revenues from selling electricity.

However, power exchanges in wholesale markets work on the basis of marginal costs for determining spot prices with suppliers having lower marginal costs that the equilibrium price being able to cover (parts of) fixed costs. In a situation with a very high contribution of capital intensive low carbon technologies with marginal costs close to zero, such as RES, all suppliers succeeding to place bids might be bidders with such RES power plants and competition at power exchanges would drive this electricity price down close to zero. Obviously, close to zero prices over very long time segments every year would not be a sustainable solution in such a scenario, as the necessary capital expenditure and investment under such market structure could not be financed from selling revenues and such a scenario would not materialise. While PRIMES, presenting functioning scenarios, presents economically sustainable electricity prices, this issue appears to be an institutional challenge for the transition to a low carbon electricity system, especially for one that is nearly entirely based on RES.

9 Average electricity prices in this table relate to a somewhat different customer base compared with electricity prices shown in Part A by including also energy branch customers in addition to those in final demand sectors; this explains the slight differences in average prices (e.g. for 2005 between 109.3 €/MWh when including the energy branch and 110.1 €/MWh when excluding it).

2.4 Other sectors

Heating and cooling: distributed heat/steam and RES

Demand for distributed heat in the decarbonisation scenarios rises compared to current level but is 2%-10% lower by 2030 as compared to the Reference scenario, with the greatest decline occurring in the high RES scenario. The decrease is more pronounced towards 2050 with 46% decrease as compared to Reference scenario in the High RES scenario; 26% decrease in the Energy Efficiency scenario and at least -20% decrease in other decarbonisation scenarios. The High RES scenario shows lowest distributed heat demand after 2025 due to the highest penetration of RES in power generation which leads to decrease of CHP[10] and due to the shift towards electricity use for heating reducing especially district heating from fossil fuels.

When comparing results for distributed heat between Reference and decarbonisation scenarios, it is important to note that final energy demand in the decarbonisation scenarios is 34% - 40% lower in 2050 than under reference developments (around 10% lower in 2030).

The biggest decrease as compared to the Reference scenario in 2050 occurs in the residential sector (-63% in High RES scenario and -32-42% in all other decarbonisation scenarios) reflecting stringent energy efficiency policies in buildings. Demand stays at current levels of around 240 TWh until 2015 and then gradually declines to 69 TWh in the High RES scenario and 126 TWh in the Low nuclear by 2050, showing the higher distributed heat demand among the decarbonisation cases.

The decrease in the tertiary sector is important as well with -43% in the Energy Efficiency scenario and at least -31% in all other scenarios. The demand peaks in 2015 at 120 TWh and goes down to 52 TWh in Energy Efficiency scenario and around 60 TWh in other decarbonisation scenarios.

Contrarily to residential and tertiary, industrial demand for heat increases massively from 160 TWh in 2005 to reach 503 TWh in High RES scenario and up to 733 TWh in Low nuclear/High CCS scenario by 2050. Industrial demand is still lower as compared to Reference scenario by at least 17% in all decarbonisation scenarios and by -43% in High RES scenario. However, industry needs steam for some processes that can hardly be substituted by other fuels.

Heat consumption is also rising in the energy branch from 54 TWh in 2005 to 71-77 TWh in 2050, with the Energy Efficiency and delayed CCS scenarios at the lower end of the range and the Low Nuclear scenario at the upper one.

Following the diverging trends in different sectors the shares of sectors in total distributed heat changes significantly up to 2050.

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10 CHP leads to emission reductions compared to conventional systems, but is only decarbonised when fired with biomass. The use of biomass in PRIMES is optimally allocated endogenously and might therefore not be used for CHP.

Table 32: Heat/steam final consumption

	2005		2050			
			Reference scenario		Decarbonisation scenarios	
Industry	161TWh	31%	880 TWh	76%	503 - 733 TWh	81- 80%
Households	240 TWh	46%	186 TWh	16%	69 - 126 TWh	11 - 13%
Tertiary	116 TWh	22%	92 TWh	8%	52 - 64 TWh	8 - 7%
Final demand	517 TWh	100%	1.159 TWh	100%	627 – 923 TWh	100%

With lower final energy demand under decarbonisation, the share of distributed heat in total heating in the residential, services and agriculture sectors rises somewhat from current level of slightly over 11% in most scenarios, except for the High RES scenario. This decrease in the share of distributed heat is compensated by the increased direct use of biomass for heating, which soars from approx. 13.5% in 2010 to approx. 33% in 2050 in the High RES scenario.

Table 33: Share of distributed heat in total heating for residential and tertiary

	2020	2030	2050
CPI	11.6%	12.0%	12.0%
Energy Efficiency	12.0%	12.8%	13.3%
Div. Supply Technology	11.6%	12.4%	13.4%
High RES	11.6%	11.4%	8.5%
Delayed CCS	11.6%	12.4%	12.4%
Low Nuclear	11.6%	12.5%	13.7%

Heat and steam generation

Heat from CHP rises from 473 TWh in 2005 to 1030 TWh by 2025 in the High RES scenario and then declines to 682 TWh by 2050. In other scenarios, including Energy Efficiency, the rise continues until 2035 with the highest CHP generation in the Low nuclear scenario at 1113, exhibiting a slight decline thereafter. CHP heat production in 2050 covers a range from 682 TWh in the high RES scenario to 1019 TWh in the low nuclear case. As in the Reference scenario the growth is driven by support policies resulting from the application of the CHP directive and ETS carbon prices.

CHP share in power generation is the highest in the Low nuclear scenario reaching 22% in 2030. This share in 2030 is the lowest in the High RES scenario at 19%. By 2050, CHP share decline in all scenarios to 18% in Low nuclear and to 11% in High RES scenarios reflecting higher penetration of wind and solar in power generation (no combined production of heat possible) and electrification of heating in combination with energy efficiency policies to reduce demand for heat.

District heating is already declining from its 2000 levels of almost 190 TWh and this decline continues in the Reference scenario as well as in decarbonisation scenarios to 109 TWh in the Reference scenario and 29 -52 TWh in decarbonisation scenarios. The development of district heating is due to its benefits in reducing emissions in the short and medium term but in the long run, similarly to CHP plants, if district heating boilers do not use biomass, they emit GHG.

RES in heating and cooling

The modelling of energy demand formation by sector includes heating and cooling requirements as well as a detailed coverage of various ways of satisfying these needs including distributed heating and cooling from co-generation and district heating. As can be seen from table 34, there is very significant progress in all decarbonisation cases regarding the share of RES in heating and cooling. The RES share in heating and cooling doubles between 2005 and 2020 in all scenarios, reaching at least 44% by 2050 under decarbonisation. The highest share of well over 50% in 2050 is achieved in the High RES scenario.

Table 34: Percentage share of RES in gross final consumption of heating and cooling

% share	2020	2030	2050
CPI	20.9	22.7	23.8
Energy Efficiency	21.0	23.3	44.9
Div. Supply Technology	20.9	23.8	44.0
High RES	20.9	26.8	53.5
Delayed CCS	20.9	24.2	44.9
Low Nuclear	20.8	24.3	44.6

Transport

In the decarbonisation scenarios, transport energy demand is projected to decline by close to 40% below Reference in 2050 due to active policies for tightening CO2 standards (essentially impacting on fuel efficiency), taxation, internal market and infrastructure measures11. The highest energy savings, in order of 155 Mtoe, are achieved in the Energy Efficiency scenario but all decarbonisation scenarios deliver savings in the same order of magnitude (around 150 Mtoe). Over 60% of these energy savings originate from passengers transport.

Energy intensity in passenger transport improves by slightly over 60% between 2005 and 2050 in the decarbonisation scenarios, mainly due to the enforcement of such efficiency standards. For freight transport, the efficiency standards together with measures encouraging a shift in modal choices lead to around 40% decrease in the energy intensity.

The EU transport system would remain extremely dependent on the use of fossil fuels in the Reference scenario. Oil products would still represent 88% of the EU transport sector final demand in 2030 and 2050 in the Reference scenario. Consumption of oil would decrease by 11% by 2050, relative to the Reference scenario, in the Current Policy Initiatives scenario mainly driven by the revision of the Energy Taxation Directive.

In the decarbonisation scenarios, final consumption of oil by transport is expected to decrease by almost 70% in 2050, relative to the Reference scenario; the oil share in final demand would amount to around 45%. This decline is compensated to a certain extent by the rise in the electricity demand by road and rail transport and the increased demand for biofuels, especially in aviation, inland navigation and long distance road freight, where electrification

[11] The decarbonisation scenarios reflect the transport policy measures included in the White Paper "Roadmap to a Single Transport Area – Towards a competitive and resource efficient transport system" (COM (2011) 144) with highest impact on energy demand in transport.

is not or less an option. Biofuels would represent slightly below 40% of energy consumption in aviation and inland navigation and 41% in long distance road freight by 2050. The role of biofuels in energy demand by passenger cars and light duty vehicles would be more limited, ranging between 13% and 15%. Electricity would provide around 65% of energy demand by passenger cars and light duty vehicles in all decarbonisation scenarios. Electro-mobility would need to be supported by the upgrade of Europe's networks towards a European super grid and decarbonisation of electricity sector.

As a result of the higher demand for electricity and sustainable biofuels, the share of renewables in transport would increase by 2050, ranging between 62% and 73%. This difference between the decarbonisation scenarios can be explained by the different power generation mix, despite similar shares of biofuels and electricity demand in energy consumption by transport mean. Therefore, the highest share of renewables in transport is achieved in the High RES scenario.

2.5 Security of supply

Import dependency in 2030 does not change substantially in decarbonisation scenarios as compared to Reference scenario and Current Policy Initiatives scenario due to decline in both gross inland consumption and imports. There is however a substantial decrease in 2050, driven by increased use of domestic resources, mainly renewables. Import dependency is only 35% in High RES scenario (compared to 58% in the Reference scenario and Current Policy Initiatives scenario) and 39-40% in all other decarbonisation scenarios besides Low nuclear scenario (45%) where it is higher due to significant use of fossil fuels with CCS. Decarbonisation will significantly reduce fossil fuel security risks.

Table 35: Import dependency

%	2009	2030	2050
1.Reference	53.9	56.4	57.6
1 bis Current Policy Initiatives		57.5	58.0
2. Energy efficiency		56.1	39.7
3. Diversified supply technologies		55.2	39.7
4. High RES		55.3	35.1
5. Delayed CCS		54.9	38.8
6. Low nuclear		57.5	45.1

Large scale electrification combined with more decentralised power generation from variable sources brings other challenges to high quality energy service at any time. An adequate stability of the grid is a precondition for the consistent modelling of all scenarios; that is why differences in indicators such as reserve margin are rather small.

Utilisation rates of electric capacities decrease from 49% in 2005 to 36% in 2050 in the Reference scenario and to a range of 25% (High RES) to 33% (Diversified supply technologies scenario) in decarbonisation scenarios. This reflects higher requirements for reserve power and balancing services in order to keep supply of electricity reliable and secure in all scenarios.

All scenarios see a high increase in the share of variable RES in the electricity supply; this naturally leads to higher balancing requirements in the system. In the long term the balancing is met to the greatest extent by increased pumped storage (to the extent there is still increased potential available), the development of flexible gas-based units, higher import-exports and in the case of very high RES penetration with hydrogen based balancing. Thermal power plants, mainly gas fired ones, remain available as reserve power and provide ancillary services. The reduction in utilisation rates of thermal power plants is driven by economic considerations, not by predetermined exogenous inputs.

Utilisation rates for steam stay stable in the Reference scenario at around 43% but decrease to a range of 26% (High RES) and 36% (Diversified supply technologies scenario) in decarbonisation scenarios. Energy savings and electrification in heating which takes place in the decarbonisation scenarios limits the scope for further expansion of distributed heat/steam and CHP, except in cases of production with carbon free (or very low carbon content) resources (e.g. biomass, gas mixed with hydrogen).

Import-export flows of electricity are also driven by economic considerations in the internal market, for which simulations were carried out separately for every scenario. This allows for trade between countries and therefore for optimal use of the interconnections and generation capacities across countries, taking into consideration the limits of the interconnector capacities, which have been adapted according to the challenges posed by the different scenarios. . The simulation thus allows for a better cost optimisation of the power generation system across the EU Member States in the context of stable grid operations at European level at any time.

It emerges clearly from table 36 that decarbonisation would involve greater electricity trade among Member States, which is most pronounced in the case that decarbonisation focuses overwhelmingly on RES.

Table 36: Grid stability related indicators

Power Reserve Margin (%)			
Ratio of dispatchable nominal capacities with RES contributing with (small) capacity credits divided by total peak demand (EU net imports not included)			
	2020	2030	2050
Reference	24,1	16,0	17,7
Scenario 1bis	26,8	19,1	22,0
Scenario 2	29,1	24,6	27,8
Scenario 3	25,7	21,2	23,8
Scenario 4	25,6	21,7	32,2
Scenario 5	25,7	21,7	25,9
Scenario 6	25,1	20,4	26,3

Volume of electricity trade (TWh)			
Sum of all export and import flows of electricity as simulated by the model (lower than in reality)			
	2020	2030	2050
Reference	212,1	217,6	222,3
Scenario 1bis	255,8	307,5	322,8
Scenario 2	303,1	450,8	618,9
Scenario 3	326,6	476,1	623,6
Scenario 4	304,4	602,8	1040,9
Scenario 5	322,8	489,0	648,6
Scenario 6	317,8	482,5	599,1

Contribution of electricity storage (%)			
Extraction of electricity from storage systems as percentage of gross final demand of electricity			
	2020	2030	2050
Reference	1,2	1,1	1,3
Scenario 1bis	1,1	1,1	1,1
Scenario 2	1,1	1,3	1,0
Scenario 3	1,1	1,2	1,0

Volume of electricity trade as % of gross final electricity demand			
Sum of all export and import flows of electricity as simulated by the model (lower than in reality) as percentage of gross final electricity demand			
	2020	2030	2050
Reference	6,0	5,7	4,9
Scenario 1bis	7,4	8,6	7,4
Scenario 2	9,0	13,7	15,4
Scenario 3	9,4	13,2	13,6

Scenario 4	1,1	1,2	6,5	Scenario 4	8,8	17,0	24,3
Scenario 5	1,1	1,2	1,0	Scenario 5	9,3	13,6	14,3
Scenario 6	1,1	1,2	1,1	Scenario 6	9,1	13,7	13,4

Share of decentralised power generation (%)			
Share of generation by small scale power plants which are connected to low voltage and medium voltage grid over total net power generation			
	2020	2030	2050
Reference	6,3	9,1	10,6
Scenario 1bis	6,5	10,0	13,9
Scenario 2	7,1	13,1	21,8
Scenario 3	7,2	13,0	20,9
Scenario 4	7,2	17,3	31,3
Scenario 5	7,2	13,1	21,4
Scenario 6	7,1	14,0	24,3

Investment in electricity grids (bn EUR'08)			
Investment expenditure on electricity networks over the indicated time period			
	2006-2020	2021-2030	2031-2050
Reference	389,9	308,0	649,0
Scenario 1bis	387,3	291,1	773,6
Scenario 2	405,4	352,2	860,5
Scenario 3	436,8	416,1	958,9
Scenario 4	434,4	535,5	1323,5
Scenario 5	436,2	420,4	960,9
Scenario 6	438,9	424,6	1029,0

2.6 Policy related indicators

Emissions and ETS prices

All decarbonisation scenarios achieve 80% GHG reduction and close to 85% energy related CO2 reductions (83.4-84.4%) in 2050 compared to 1990 as well as equal cumulative emissions over the projection period. In 2030, energy-related CO2 emissions are between 38-41% lower, and total GHG emissions reductions are lower by 40-42%. In 2040, energy related CO2 emissions are 63-66% below their 1990 level, while total GHG emission fall by 61-63%.

Power generation would be almost completely decarbonised with CO2 emissions in 2050 plummeting 96-99% compared with 1990. CO2 emission reductions by 2050 are particularly high (minus 86-88%) also in the services/agriculture sector as well as in households (minus 85-87%). Energy related CO2 emissions in industry fall 77-79% below their 1990 level. Transport CO2 emission are 60-62% lower in 2050 compared with 1990.

The ETS price rises moderately from current level until 2030 and significantly in the last two decades providing support to all low carbon technologies and energy efficiency. Concrete policy measures such as those pushing energy efficiency and/or those enabling penetration of renewables depress demand for ETS allowances which subsequently lead to lower carbon prices. Carbon prices are the lowest in the Energy Efficiency scenario where energy demand is the lowest followed by High RES scenario (second lowest in 2030 and 2040) and the Diversified supply technology scenario (second lowest in 2050). Delay in penetration of technologies (CCS) or unavailability of one decarbonisation option (nuclear) put an upwards pressure on demand for allowances and ETS prices.

Table 37: ETS prices in €'08/t CO2

	2020	2030	2040	2050
Reference scenario	18	40	52	50
Current Policy Initiatives	15	32	49	51
Energy Efficiency	15	25	87	234
Diversifies supply technologies	25	52	95	265
High RES	25	35	92	285
Delayed CCS	25	55	190	270
Low nuclear	20	63	100	310

The same carbon value as in the ETS applies also to non-ETS sectors after 2020 assuring cost-efficient emissions abatement in the whole economy.

CCS storage needs

Making use of the CCS option will require considerable storage capacities for CO2 over time. The Reference scenario developments, including a more optimistic picture on CCS demonstration and availability of storage sites, would require storage capacity for the cumulative CO2 emissions captured up to 2050 of 8 billion tonnes of CO2.

In the CPI scenario, CCS penetration is more moderate leading to storage requirements of 3 bn t CO2 up to 2050. The lowest storage needs come about under high RES scenario, in which case the additional storage requirements over CPI amount to 0.5 bn t CO2. The highest storage needs comes in the Low nuclear scenario leading to considerable CCS penetration, which requires almost 13 bn t CO2 storage capacity up to 2050. Also the Diversified Supply Technology scenario would require considerable storage capacity.

Table 38: CCS storage needs for power generation and industrial processes up to 2050 (in bn t CO2)

	power generation	process related CO2	total CO2
Reference	7,95	0,00	7,95
CPI	3,00	0,00	3,00
Energy Efficiency	4,08	1,52	5,59
Div. Supply Techn.	6,80	2,18	8,98
RES	1,77	1,72	3,50
delayed CCS	4,06	0,62	4,68
low nuclear	10,45	2,35	12,80

RES targets and biomass

The Reference scenario assumes that the RES target is reached in 2020. The RES share (as % of gross final energy consumption according to the definition of the RES directive) is slightly higher in all decarbonisation scenario in 2020 (21%), rises to at least 28% in 2030 and 55% in 2050. In the High RES scenario this share is at 31% in 2030 and 75% in 2050.

The share of renewables in power generation is even higher and stands at 86% in 2050 in the High RES scenario. The share in consumption is even higher, since with much more variable supply and demand some electricity produced needs to be stored and losses linked to such storage processes lead to lower consumption compared to production, i.e. reducing significantly the denominator of such a share. When calculating the RES-E share in line with the calculation of the overall RES share in gross final energy consumption, i.e. excluding energy losses linked to pump storage and hydrogen storage of electricity, the RES share in electricity consumption amounts to 97% in 2050 in the High RES case.

The share of renewables in transport (target of 10% for 2020 in the RES directive) is 1 percentage point higher in all decarbonisation scenarios in 2020; it rises to 19%-20% in 2030 and to 62%-73% in 2050. The share of renewables in transport in the High RES scenario is 20% in 2030 and even 73% in 2050. The increase between 2030 and 2050 as well as the difference to the Reference scenario and Current Policy Initiatives scenario of almost 50 percentage points in 2050 for the decarbonisation scenarios is remarkable and shows the importance of RES based decarbonisation of transport, either directly via biofuels or indirectly via RES based electricity. Decarbonisation efforts and RES share in transport are rather moderate till 2030 but rise significantly from 2030 to 2050.

The large share of RES in the scenarios is driven by a strong support for RES in the form of an implicit facilitation of RES in the scenarios. These lead to shifts in RES potential curves in the decarbonisation scenarios, allowing for more RES exploitation at a given deployment cost level, compared to the Reference scenario. This includes facilitation policies such as:

- For biomass: agricultural policies stimulating the production of energy crops, increased residue collection, and/or increased yield of crops;

- For wind: regarding on-shore it comprises the availability of more land area and a facilitation of the licensing requirements; for off-shore it also represents a facilitation of licensing and the development of technologies that allow placing off-shore power plants in deeper areas or further offshore; and

- For small scale solar PV and wind: development of smart grids and other facilitation policies.

The total use of biomass in the various scenarios is shown in table 39. Whereas the Reference and CPI scenarios have about 100 Mtoe more biomass use in 2050 compared with today's level, there is around 70-80 Mtoe additional biomass use in most decarbonisation scenarios in 2050, except for the high RES case, in which the additional biomass use amounts to around 120 Mtoe.

Table 39: Use of biomass and biofuels

ktoe	2005	Reference scenario		Current policy Initiatives	
		2030	2050	2030	2050
Total domestic biomass	86285	179649	185863	175987	188914
of which biofuels	*3129*	*35255*	*36957*	*34295*	*38912*
Biofuels in bunkers	0	0	0	133	2325
Total use of biomass	86285	179649	185863	176120	191239
		Energy efficiency		Diversified supply technologies	
		2030	2050	2030	2050
Total domestic biomass		162716	241476	172145	253209
of which biofuels		*25033*	*68393*	*26174*	*71047*
Biofuels in bunkers		553	18062	553	17995
Total use of biomass		163268	259538	172698	271204
		High RES		Delayed CCS	
		2030	2050	2030	2050
Total domestic biomass		188675	301805	172953	252893
of which biofuels		*26296*	*72453*	*26112*	*69370*
Biofuels in bunkers		553	18060	552	17523
Total use of biomass		189227	319865	173505	270415
		Low nuclear			
		2030	2050		
Total domestic biomass		175360	257226		
of which biofuels		*26135*	*70794*		
Biofuels in bunkers		553	17981		
Total use of biomass		175913	275206		

Biofuel consumption rises by a factor of more than ten between 2005 and 2050 under current policies to reach 37-39 Mtoe in 2050. Decarbonisation of transport requires substantially greater biofuels use, which increases to 68-72 Mtoe in 2050, with the highest levels being reached in the High RES and Diversified Supply Technology scenarios.

2.7 Overall system costs, competitiveness and other socio-economic impacts

This section deals with the costs for providing the energy services to the EU economy and society. One key element of such costs is the external fuel bill, i.e. the amount of money that they EU economy has to pay to the outside world for procuring all the net imports of oil, gas and solid fuels from the rest of the world.

The **external fuel bill** arising from the net imports of fossil fuels decreases below 2005 levels in all decarbonisation scenarios by 2050. This result stems from the pursuit of this major decarbonisation as a part of a global effort with industrial countries as a group reducing GHG emissions by 80%. In such a global setting, fossil fuel import prices will be much lower (see part on assumptions) and actual imports of fossil fuel will be much lower, too. These both effects reduce the expenditure for each of the fossil fuels and thereby the total external fuel bill of the EU. The decrease of the fuel bill in the decarbonisation scenarios is smallest in the

Low Nuclear scenario at 31% and highest in the high RES scenario with 43% with RES replacing most fossil fuels.

Compared with current level, all decarbonisation scenarios increase the external fuel bill in 2030, but to much lower levels than the Reference and Current Policy Initiative scenarios. While the external fuel bill would double between 2005 and 2030 under Reference and Current Policy Initiatives developments, this increase would be limited to around 40% under these decarbonisation policies.

Table 40: External fossil fuel bill (in bn € (08))

	2005	Reference		CPI	
		2030	2050	2030	2050
Bn. EUR'08	269.1	549.2	752.2	531.9	704.2
Diff. to 2005		104%	180%	98%	162%
		Energy Efficiency		Diversified supply technologies	
		2030	2050	2030	2050
Bn. EUR'08		364.5	165.7	379.0	180.1
Diff. to 2005		35%	-38%	41%	-33%
		High RES		Delayed CCS	
		2030	2050	2030	2050
Bn. EUR'08		374.8	154.2	377.0	180.4
Diff. to 2005		39%	-43%	40%	-33%
		Low nuclear			
		2030	2050		
Bn. EUR'08		382.0	186.4		
Diff. to 2005		42%	-31%		

Savings in the external fuel bill are most striking in 2050. Compared with Current Policy Initiatives, the EU economy could save in 2050 between 518 and 550 bn € (08) by going this strong decarbonisation route under global climate action. The largest energy bill savings come about in the high RES scenario. Such fuel bill savings have strong impacts on overall energy system costs.

Total costs for the entire energy system include capital costs (for energy installations such as power plants and energy infrastructure, energy using equipment, appliances and vehicles), fuel and electricity costs and direct efficiency investment costs (house insulation, control systems, energy management, etc), the latter being also expenditures of capital nature. Capital costs are expressed in annuity payments. Total costs exclude disutility and auction payments.

> Auction payments are expenditures for individual actors/sectors that are not costs for the economy as a whole, since the auctioning revenues are recycled back to the economy. Disutility costs are a concept that captures losses in utility from adaptations of individuals to policy impulses or other influences through changing behaviour and energy consumption patterns that might bring them on a lower level in their utility function. Such disutility costs correspond to a monetary estimation (income compensating variation) of lower utility from useful energy services (lighting, heating, mobility, etc.) resulting from a more rational use behaviour by consumers who for example adjusts thermostats, switch lighting off or travel less in order to adapt to higher costs of useful energy services. Such costs monetisation captures relevant issues regarding new consumption patterns especially for a short to medium time horizon, but becomes more challenging and uncertain in the long term, given that monetisation requires the comparison with a counterfactual development assuming unchanged tastes, habits and values over up to 40 years.[12]

[12] The PRIMES model having a micro-economic foundation, deals with utility maximisation and can calculate such perceived utility losses via the concept of compensating variations. However, this

Table 41: Energy system costs

Average annual energy system costs 2011-2050

Bn. EUR'08	Ref	CPI	High Energy effic.	Div. supply techn.	High RES	Delayed CCS	Low nuclear
Capital cost	955	995	1115	1100	1089	1094	1104
Energy purchases	1622	1611	1220	1295	1355	1297	1311
Direct efficiency inv. costs *	28	36	295	160	164	161	161
Total system cost excl. all auction payments and disutility **	2582	2619	2615	2535	2590	2525	2552

Absolute Difference to Reference

Bn. EUR'08	High Energy effic.	Div. supply techn.	High RES	Delayed CCS	Low nuclear
Δ Capital cost	160	145	134	139	149
Δ Energy purchases	-402	-327	-267	-325	-312
Δ Direct efficiency inv. costs *	267	132	135	133	133
Δ Total system cost excl. all auction payments and disutility **	33	-47	8	-57	-29

Absolute Difference to CPI

Bn. EUR'08	High Energy effic.	Div. supply techn.	High RES	Delayed CCS	Low nuclear
Δ Capital cost	120	105	94	99	109
Δ Energy purchases	-391	-316	-256	-314	-300
Δ Direct efficiency inv. costs *	260	125	128	126	125
Δ Total system cost excl. all auction payments and disutility **	-4	-84	-29	-94	-67

Percentage change to Reference

%	High Energy effic.	Div. supply techn.	High RES	Delayed CCS	Low nuclear
Capital cost	16,8	15,2	14,0	14,6	15,6
Energy purchases	-24,8	-20,2	-16,5	-20,0	-19,2
Direct efficiency inv. costs *	937,3	462,4	475,0	466,9	465,5
Total system cost excl. all auction payments and disutility **	1,3	-1,8	0,3	-2,2	-1,1

Percentage change to CPI

%	High Energy effic.	Div. supply techn.	High RES	Delayed CCS	Low nuclear

concept has to assume that preferences and values remain the same, even over 40 years, and has to compare utility with a hypothetical state of no policy or no change in framework conditions. Examples of such decreases are lowering thermostat in space heating, reducing cooling services in offices, switching light off, staying home instead of travelling, using a bicycle instead of a car, etc.

Capital cost	12,0	10,5	9,5	10,0	10,9
Energy purchases	-24,3	-19,6	-15,9	-19,5	-18,6
Direct efficiency inv. costs *	729,5	349,8	359,9	353,4	352,2
Total system cost excl. all auction payments and disutility **	-0,1	-3,2	-1,1	-3,6	-2,5

* Include costs for insulation, double/triple glazing and for efficiency enhancing changes in production processes not accounted for under energy capital and fuel/electricity purchase costs;

** These macroeconomic costs do not include ETS auctioning payments that represent a cost from the individual economic actors point of view, but do not present a cost to society given that auctioning revenues are recycled back to the economy (societal perspective); auctioning payments are partly included in energy purchase costs (e.g. in electricity prices) and partly paid directly by actors subject to ETS; total costs in table 41 differ from the sum of the items shown; table 42 on additional information below gives more detail

Table 42: Additional information on auctioning payments, disutility and total costs from the individual economic actor's point of view (bn € (08) per year on average in 2011-2050)

Bn. EUR'08	***Ref***	***CPI***	***High Energy effic.***	***Div. supply techn.***	***High RES***	***Delayed CCS***	***Low nuclear***
Auctioning payments	30	28	20	27	24	36	30
Total energy system cost (a)	2612	2647	2635	2562	2614	2561	2583
Disutility costs (b)	92	112	153	174	181	211	190
Total energy system costs including auction payments and disutility (c)	2704	2759	2788	2735	2795	2773	2772

(a) From the individual economic actors' point of view, including direct and indirect (via purchase of e.g. electricity) auctioning costs, but excluding disutility costs;

(b) Disutility costs are costs stemming from behavioural change, such as changing lighting quality, lowering thermostat temperature, replacing fuel consuming mobility with other types of mobility (e.g. bikes) or telecommunication that are not accounted for by expenditure flows in the model, but change the level of utility of consumers; such changes are linked to carbon values in non-ETS (which do not represent a cost in cash terms), but are a proxy for policy measures bringing about such behavioural change; direct costs of such change in terms of investment and fuel bills are accounted for in the normal modelling procedure; given the long time horizon and possibly changing preference, the estimation of disutility costs is surrounded with uncertainty.

(c) From the individual economic actors' point of view, including direct and indirect (via purchase of e.g. electricity) auctioning costs as well as disutility costs;

NB: The lower system cost (without auctioning revenue and disutility) in the Delayed CCS scenario compared with the Diversified supply technologies scenario (that is unrestricted regarding technology) is not present when auctioning revenues and disutility costs are included, i.e. the point of view of the economic actors is taken (numbers denoted with (c) above). In this case, the Diversified Supply Technology scenario has the lowest costs. The modelling approach simulates the system from the point of view of economic actors, who perceive auctioning payments and disutility as cost to them that they want to minimise. Disutility costs are however surrounded with uncertainty given the long time horizon and their dependence on preferences and values. Moreover they represent a monetary equivalent in terms of imputed income compensation of changes in utility and are not associated with payments represented in the process of modelling (e.g. energy purchases, investment sums). Given the uncertain and somewhat controversial nature of disutility costs for a 40 year time horizon this long term assessment of economic impacts reports on costs without disutility. Furthermore, taking a macro-economic perspective auctioning revenues can be seen as transfers as they are supposed to be recycled, justifying their exclusion from the macro-economic cost evaluation.

The average additional energy system cost per year from 2011 to 2050 compared with the Reference and Current Policy Initiatives scenario are rather small due to the pursuit of this major decarbonisation as a part of a global effort. Given that the Current Policy Initiatives scenario is the most up to date current trend scenario and that all decarbonisation scenarios base themselves on this updated baseline, the following comparison starts from the CPI scenario (1bis).

The Delayed CCS scenarios and the Diversified Supply Technologies have the lowest level of average annual energy system costs, representing even a cost saving compared with CPI (of 94 bn €(08) and 84 bn €(08), respectively) given the large fossil fuel import cost savings discussed above. These are scenarios, in which there is a rather high nuclear penetration in addition to substantial RES penetration and strong energy efficiency progress. Given these fossil fuel import bill effects, also the Low Nuclear Scenario would produce average annual fuel bill savings of 67 bn € (08) when compared with CPI. The High RES scenario gives rise to a annual energy system cost saving of 29 bn € (08) when compared with CPI, while the annual cost savings for the Energy Efficiency scenario amount to 4 bn €(08).

The cost savings in the Energy Efficiency scenario are smaller (4 bn €) given that very high energy efficiency progress requires strong action on the building stock entailing major expenditure for accelerated building renovation, in addition to costs for other energy efficient equipment including the costly transition to electric and plug in hybrid vehicles. High renovation rates are one of the salient features of the energy efficiency scenario. Electro-mobility also provides for greater energy efficiency in the system. However, this higher cost does not disqualify energy efficiency policies as such, as strong energy efficiency policies leading to substantial improvements and energy savings, are present in all scenarios. The Energy efficiency scenario just shows that there are certain limits from where on other decarbonisation routes are less costly than further reductions of energy consumption.

All scenarios show higher annual costs in the last two decades 2031-2050 reflecting mainly increased investments in transport equipment as the major transition to electric and plug in hybrids vehicles is projected after 2030. In High RES scenario costs are also linked to significant expansion of RES based power generation capacity.

Cumulative auction payments are lowest in Energy efficiency scenario due to the reduced energy consumption, decreasing emissions and therefore the necessity to buy ETS permits. The scenario with the highest auction revenues is Delayed CCS where the delay in the use of CCS leads to high carbon prices in the long-term to ensure the achievement of the decarbonisation target via the uptake of this technology in these later years. The PRIMES model works with perfect foresight in the supply side module, therefore the high carbon prices are expected, influencing choices already in previous years. The auction revenues represent an equivalent of around 1% of total cumulative energy system costs.

When relating the cumulative costs to the GDP (which remains constant in these scenarios) the **ratio of costs to GDP** is similar across the scenarios (around 14.1% to 14.6%) exhibiting costs at the low end of the range in case of diversified supply technologies and delayed CCS.

Table 43: Energy system costs (without auction payments and disutility) related to GDP

	Cumulative costs as percentage of GDP (*)
Reference	14.37%
CPI	14.58%

Energy Efficiency	14.56%
Diversified Supply Technology	14.11%
High RES	14.42%
Delayed CCS	14.06%
Low Nuclear	14.21%

Change in cost structure: fixed costs versus variable costs

The composition of energy costs changes over time and varies across scenarios. The share of fixed cost (capital costs including for e.g. insulation) rises in all scenarios. Following larger capital expenditure for e.g. power generation, grids, energy efficiency investment over time energy, the progress in energy efficiency, greater use of technologies with low operating costs (most RES) and lower world fossil fuel prices in the decarbonisation scenarios bring lower fuel and emission allowances costs. Consequently, the share of capital costs increases over time, especially in the Energy Efficiency and High RES scenarios, which have the highest fixed cost shares (see table 44).

Table 44: Share of fixed costs* in total energy costs (averages over the time periods indicated)**

	2011-2030	2031-2050	2011-2050
Reference	44%	53%	49%
Current Policy Initiatives	45%	54%	50%
Energy Efficiency	52%	74%	65%
Diversified Supply Technologies	50%	70%	62%
High RES	50%	71%	63%
Delayed CCS	50%	70%	62%
Low Nuclear	50%	70%	62%

* capital costs for equipment, appliances, and energy efficiency investment (e.g. insulation), more efficient and cleaner vehicles

** total energy cost from the economic actors' point of view: including auctioning costs

Energy related costs for companies

Energy related costs in relation to sectoral value added rise from 5.8% in 2005 to 7.8% in 2030 in the Reference/CPI cases and to around 7.5% in the decarbonisation scenarios. In 2050, under current policies, this indicator declines to 7.5% and even more so in the decarbonisation scenarios falling to under 7%. Long term energy costs relative to value added of companies under decarbonisation are lower in the decarbonisation cases than under current policies thanks to substantial global decarbonisation efforts. Whereas relative costs for stationary use (heating, process energy, appliances, lighting, etc) in the decarbonisation scenarios remain at the current level by 2030, there is a strong increase in costs related to value added for transport services. After 2030, both stationary and transport energy costs decline somewhat when related to value added. Overall, energy costs relative to value added in 2050 are only somewhat higher than they were in 2005 under decarbonisation, whereas there would be a much more pronounced increase of such costs in the absence of such decarbonisation under significant global climate action.

Table 15: Energy related costs of companies

%	2005	Reference		Scenario 1 bis	
		2030	2050	2030	2050
Ratio of energy related costs to value added	5.8	7.8	7.5	7.8	7.5
of which stationary uses	4.3	4.8	4.5	4.6	4.3
of which transportation uses	1.5	3.0	2.9	3.1	3.1
		Scenario 2		Scenario 3	
		2030	2050	2030	2050
Ratio of energy related costs to value added		7.6	6.6	7.4	6.4
of which stationary uses		4.4	3.9	4.2	3.8
of which transportation uses		3.2	2.7	3.1	2.6
		Scenario 4		Scenario 5	
		2030	2050	2030	2050
Ratio of energy related costs to value added		7.3	6.9	7.4	6.3
of which stationary uses		4.3	4.1	4.2	3.8
of which transportation uses		3.0	2.7	3.2	2.5
		Scenario 6			
		2030	2050		
Ratio of energy related costs to value added		7.5	6.5		
of which stationary uses		4.3	3.8		
of which transportation uses		3.2	2.7		

Energy intensive industries face particularly high energy costs for their highly energy consuming production processes. Five industrial sectors (iron and steel, non-ferrous metals, non metallic mineral products, chemicals, paper and pulp industries) have such high energy costs and are therefore particularly concerned by potential changes from decarbonisation in the energy component of their costs. Table 46 shows for these energy intensive industries combined the ratio of energy related costs for production processes and other stationary use, on the one hand, and their value added, on the other.

Table46: Ratio of energy related costs to value added for energy intensive industries

	2005	2030	2050
Reference	33.7%	40.8%	40.5%
CPI		39.4%	39.5%
Energy Efficiency		35.6%	30.6%
Diversified Supply Technologies		36.4%	32.4%
High RES		36.1%	34.8%
Delayed CCS		36.5%	33.2%
Low Nuclear		37.1%	33.5%

Energy costs of energy intensive industries relative to value added would increase under Reference and CPI developments. This development stems also from rising world fossil fuel prices under current trends. It is worth noting that under global climate action bringing with it lower energy import prices and due to substantial energy efficiency progress, the ratio of energy costs to value added in energy intensive industries would decline in all decarbonisation scenarios – most markedly in the Energy Efficiency scenario

Effects of fragmented climate action: competitiveness and energy consequences of safeguards for energy intensive industries

This Energy Roadmap has assumed the implementation of the European Council's decarbonisation objective that includes similar efforts by industrialised countries as a group. The analysis presented focuses on energy consequences. A more comprehensive analysis of different global paths to decarbonisation was presented in the Low Carbon Economy Roadmap 2050[13] exploring impacts of three global climate situations: a) business as usual; b) global climate action and c) fragmented action. Fragmented action assumes strong EU climate action that is however followed globally only by the low end of Copenhagen pledges up to 2020 and afterwards the ambition level of the pledges is assumed to stay constant. It analyses impacts on energy intensive industries (EII) both in a global macroeconomic modelling framework to address carbon leakage issues and by means of energy system modelling to address effects of fragmented action, including electricity costs for companies. Electricity costs are, in fact, higher in the fragmented action scenarios as compared to global action scenarios due to higher energy import prices. On the other hand, carbon prices are lower under fragmented action.

A "fragmented" action scenario including measures against carbon leakage was not analysed in this IA report as the challenges for the energy sector arising from decarbonisation are the biggest under "global climate action" assumption, given that fragmented action with measures against carbon leakage will deliver lower GHG reductions by 2050. Decarbonisation scenarios that accommodate action against carbon leakage under fragmented action would either go for lower ambitions in terms of GHG reduction or would have measures included that imply such lower efforts for energy intensive industries and consequently for the total energy system[14]. With action on carbon leakage the challenge for the transition in the energy system would be smaller given lower efforts in parts of the system. Such results are however modified through countervailing effects from lower world fossil fuel prices under global action that encourage somewhat higher energy consumption and emissions. In any case, the implementation of measures will be crucial. The real difference for industrial and thereby climate policy might come from the concrete design of policy instruments that is not discussed in this Energy Roadmap Impact Assessment (e.g. special provisions on ETS for EII).

From the analysis undertaken for the Low Carbon Economy Roadmap it can be concluded that under fragmented action with the EU reducing emissions much more than other regions, certain industries supplying low carbon technologies would benefit from improved competitiveness due to higher internal demand and first mover advantages. However, EII would suffer from higher costs for allowances and/or significant mitigation costs in order to avoid the need to purchase such allowances. Furthermore, under fragmented action they

[13] Impact assessment report SEC(2011)288 final, section 5

would not benefit from the fuel and electricity price reductions stemming from a global climate deal that lowers world fossil fuel prices.

This situation of fragmented action might require countervailing action to combat carbon leakage, which was investigated in the Low Carbon Economy Roadmap, notably by exploring a scenario, in which energy intensive industries (iron and steel, non-ferrous metals, chemicals, non metallic minerals, paper and pulp industries) would benefit from the same ETS prices that prevail in the reference scenario, whereas other sectors would be exposed to higher carbon costs. These provisions have only a limited impact on the CO2 emission reduction of all sectors, which instead of reaching minus 86% on 1990 under fragmented action (85% under global action) would amount to 78% with these specific provisions for EII. Clearly, the CO2 emission reduction for EII, i.e. their level of effort, would be reduced more markedly, falling from 87% reduction below 1990 under fragmented action (88% under global action) to only 51% by 2050.

These measures keeping the ETS price for energy intensive industries at the reference case levels lead to significant cost savings for purchasing fuel, electricity, steam and energy using equipment. Compared with the reference case situation with no additional climate action, the average costs in 2011-2050 decrease by 6 bn € (08) annually over 40 years. Higher energy, especially electricity prices from decarbonisation action together with the still significant carbon price signal lead to significant energy savings in energy intensive industries (22.7% in 2050 from Reference).

These cost savings take into account that electricity prices rise significantly under fragmented action (7% in 2050 compared with Reference) and this to a higher degree than under global action given that the cost reducing effect through lower fossil fuel input prices (global action reducing world fossil fuel demand) would not materialise. Electricity prices in 2050 would be 6 % lower on average under global climate action compared with fragmented action with specific measures for EII.

Under global action, the energy saving effect of energy intensive industries is reinforced through higher carbon prices, entailing even greater energy savings. Combined with lower fossil fuel import and therefore final consumer prices, there would be additional cost savings, amounting to 21 bn € per year from 2011 to 2050 when comparing global climate action with fragmented action with less effort for EII.[15]

Table 47 compares the energy related results of decarbonisation scenario under fragmented action with specific carbon leakage measures for energy intensive industries with the Reference case. It includes also a comparison between global action and fragmented action with these specific measures for energy intensive industries. The energy results for this analysis are taken from the energy modelling results for the Low Carbon Economy Roadmap, which includes, in addition to the Reference scenario, the Fragmented action, effective technology and less effort for EII scenario and the Effective Technology Global Action scenario.

[15] The energy modelling did not include possible changes in value added of energy intensive industries as a reaction to climate policy measures. However, the low carbon economy roadmap includes a complementary analysis of macroeconomic and industrial competitiveness effects of a fragmented action scenario (SEC (2011)650, section 5.1.3) which provides further insights on these issues.

The effective technology scenarios are driven by carbon prices and assume the absence of significant obstacles for technology penetration, especially CCS and nuclear, as well as the absence of specific strong push for RES and energy efficiency. The rationale of these scenarios is similar to the Diversified Supply Technologies scenario, which includes however recent policy initiatives, especially on energy efficiency and energy taxation as well as recent changes in nuclear policies. The most relevant comparison of energy results when dealing with carbon leakage in the case of Fragmented action, effective technology and less effort for EII is therefore in relation to Reference (no additional climate action), on the one hand, and Effective Technology under global climate action, on the other.

Table 47: Comparison of energy results for 2050* between fragmented action with specific measures for energy intensive industries (FAEII) and Reference as well as between global action and FAEII

	Less effort for EII compared with Reference	Global action compared with less effort for EII
Final energy consumption		
EII	-22.7%	-11.2%
Other sectors	-33.6%	+1.6%
Primary energy consumption	-24.1%	+2.5%
Gross electricity generation **	+10.3%	+6.6%
Average electricity prices	+7.2%	-5.7%
Energy related CO2 emissions	-72.4%	+1.2%
Import dependency	-26.2 pp	+1.3 pp
RES share in gross final energy demand	+26.6 pp	-0.3 pp
Cumulative investment expenditure in power generation	+30.1%	+1.2%
Average annual fuel, electricity and equipment costs	-6 bn	-21 bn

* For investment expenditure and costs this comparison relates to the 40 year period up to 2050
** including new uses, such as hydrogen as a means for electricity storage and for feeding into the gas grid thereby contributing to decarbonisation by lowering the carbon content of the gas supplied

Climate action with specific measures for EII against carbon leakages leads to quite significant energy consequences in 2050 compared to reference regarding energy consumption, fuel and electricity costs, prices and emissions. Import dependency would fall strongly, whereas the RES share would rise to a large extent. Investment in power generation would also need to rise strongly while average costs would fall significantly.

Energy consumption of EII would drop further significantly when undertaking decarbonisation in the context of global action, as EII would face higher carbon prices in this case (the same as other sectors). The small increase of energy consumption and emission levels (outside EII) when moving to global action stem from the markedly lower fossil fuel prices under globally reduced demand. Energy related results are either reinforced, if the policy response to climate change moved from fragmented action with specific carbon leakage measures for EII to global action without such measures, or they are modified reflecting the impacts from lower fossil fuel prices.

Energy related expenditures of households

Affordability of energy services as regards fuel and electricity costs but also equipment (insulation, more efficient appliances, etc) is one of the essential elements of the analysis. The sector that is mostly concerned is households. All decarbonisation scenarios show significant fuel savings compared to the Reference and CPI scenarios but also higher costs for energy appliances, boilers and insulation. Energy related expenditures for heating and cooling of households as well as for lighting and appliances almost double from around 2000 EUR'08/year today to 3800 to 3900 EUR'08 in 2050 in the Reference and CPI scenarios reflecting rising fuel and electricity prices and increasing direct household investments in energy efficiency. Expenditures per household amount to some 4500 EUR'08 in most decarbonisation scenarios in 2050, with expenditure per household reaching some 4800 € (08) and almost 4900 € (08) in the Energy Efficiency and high RES scenarios respectively.

It is important to note that per capita income in 2050 will also almost double from today's level, but also that households will be composed of fewer members reflecting aging and changing lifestyles. Energy costs per household exceed the Reference/CPI case level by 16-17% in 2050 in most decarbonisation scenarios. They are 25-27% higher in the Energy Efficiency and High RES scenarios, as these scenarios are particularly intensive in investment. While these costs might be affordable by an average household, vulnerable consumers might need specific support to cope with increased expenditures due to decarbonisation.

Households spend money on transport services, too. Such costs concern expenses on tickets for rail, bus, metro, air and other travel as well as costs for purchasing privately owned vehicles and paying for other fuel and operational expenses. These transport costs per household would even almost triple by 2050 reaching 3900 € (08) and 4100 € (08) in the Reference and CPI case, respectively. The strong growth of such costs reflects rising oil prices as well as changes in the vehicle fleet towards more efficient cars (hybrids, plug in hybrids, electric cars) that involve higher costs[16]. In the decarbonisation scenarios, transport related energy costs per households are lower in 2050 than under Reference or CPI developments, markedly so (broadly around 10%) under Diversified Supply Technologies and delayed CCS, given substantial improvements in energy efficiency in transport and limited price increases with respect to reference for transport fuel.

Relating the costs of households for stationary energy use (heating, appliances, etc) plus those for transport to household expenditure gives the following picture. The share of energy in household expenditure rises over time in all scenarios from 10% in 2005 to around 16% in 2030, decreasing thereafter to around 15-16% by 2050. Among the decarbonisation scenarios, the Delayed CCS and the Diversified Supply Technology scenarios have costs at the lower end of this range, whereas the High RES and Energy efficiency scenarios show 2050 costs at the upper end of the range.

[16] It should be noted that costs of engines and propulsion cannot be separated from the rest of vehicle costs and that these numbers include therefore the costs for owning the entire vehicle.

Table 48: Energy related expenditures of household for stationary use and transport

%	2005	Reference		Scenario 1 bis	
		2030	2050	2030	2050
Share of energy related costs in household expenditure	9.9	15.9	14.6	16.1	15.1
of which stationary uses	5.7	8.0	7.3	7.9	7.3
of which transportation uses	4.2	7.9	7.3	8.2	7.8
		Scenario 2		Scenario 3	
		2030	2050	2030	2050
Share of energy related costs in household expenditure		16.5	16.1	15.9	15.4
of which stationary uses		7.9	9.1	7.5	8.4
of which transportation uses		8.6	7.0	8.4	6.9
		Scenario 4		Scenario 5	
		2030	2050	2030	2050
Share of energy related costs in household expenditure		15.8	16.4	15.9	15.1
of which stationary uses		7.7	9.2	7.5	8.5
of which transportation uses		8.1	7.1	8.4	6.6
		Scenario 6			
		2030	2050		
Share of energy related costs in household expenditure		16.1	15.5		
of which stationary uses		7.5	8.5		
of which transportation uses		8.6	7.0		

Whereas companies enjoy long term energy costs relative to value added that are lower (or at most as high) as such costs under current policy initiatives, the 2050 energy costs of households relative to household expenditure generally exceed such costs without strong decarbonisation albeit only to a rather small extent, especially under Delayed CCS and Diversified Supply Technologies.

Electricity prices

Another important indicator on costs relates to final consumer prices especially the prices of electricity for industrial, household and services consumers as well as the average price. Electricity prices are calculated in such a way that total costs of power generation, balancing, transmission and distribution are recovered, ensuring that investments can be financed. Table 49 shows the average price for electricity in the EU27 for different sectors; the residential sector has the highest user price and industry the lowest as it is currently the case. In 2050, average electricity costs are highest in High RES scenario reaching 199 €/MWh. The lowest electricity prices are in Diversified supply and Energy efficiency scenario, with prices below the Reference and Current Policy Initiatives scenarios because of cheaper procurement of fossil fuels under global climate action.

Average prices of electricity are rising compared to current levels until 2030 and continue increasing in the High RES scenario. In the Energy Efficiency and Diversified Supply Technology scenarios, electricity prices remain similar to those in the Reference/CPI scenario up to 2030 thanks to lower fossil fuel input costs with lower world market prices. With somewhat higher investment or ETS costs, the other decarbonisation scenarios have slightly higher costs in 2030, exceeding Reference/CPI by around 5%. By 2050, the average price exceeds reference/CPI level markedly in the High RES scenario (around 30%) to recover costs for the high generation capacity needs including for back-up and for greater grid and storage capacities, while it remains almost at that level in the Low nuclear case (+4%). In the Diversified Supply Technologies and Energy Efficiency scenarios, electricity prices in 2050 are even below those in the Reference/CPI cases, whereas beneficial effects from lower import prices are compensated by effects from restricted choices on nuclear or delayed penetration of CCS in the respective scenarios. Electricity prices are already slightly higher than reference in Current policy Initiatives scenario reflecting less nuclear in power generation at somewhat higher costs.

It should also be noted that prices rise strongly up to 2020/30, but that after 2030 prices either fall or show an average annual price increase that is much smaller than in the period 2005-2030, which applies in particular for the High RES scenario.

Table 49: EU27 average electricity prices [17]

(Euro'08 per MWhe)		Reference		Scenario 1bis	
	2005	**2030**	**2050**	**2030**	**2050**
Average price(*)	109.3	154.8	151.1	156.0	156.9
Industry	*74.7*	*107.0*	*104.2*	*105.4*	*102.4*
Households	*140.7*	*207.2*	*201.3*	*211.7*	*212.3*
Services	*131.3*	*173.1*	*166.3*	*173.9*	*172.7*

(Euro'08 per MWhe)	Scenario 2		Scenario 3	
	2030	**2050**	**2030**	**2050**
Average price(*)	154.4	146.7	159.6	146.2
Industry	*106.8*	*110.5*	*111.2*	*108.8*
Households	*206.4*	*195.3*	*208.0*	*194.5*
Services	*168.9*	*161.5*	*171.8*	*159.8*

(Euro'08 per MWhe)	Scenario 4		Scenario 5	
	2030	**2050**	**2030**	**2050**
Average price(*)	164.4	198.9	160.4	151.9
Industry	*112.6*	*134.9*	*111.7*	*114.1*
Households	*215.6*	*285.6*	*209.1*	*200.9*
Services	*176.9*	*223.8*	*172.8*	*165.4*

(Euro'08 per MWhe)	Scenario 6	
	2030	**2050**
Average price(*)	168.2	157.2
Industry	*118.8*	*119.2*
Households	*218.4*	*208.3*
Services	*180.9*	*171.6*

(*): Average price over all consumer types, including final consumers and energy branch

Diesel prices

Another pertinent indicator on costs across scenarios is the price of diesel, which is relevant for both passenger transport (in private cars and buses/coaches) and freight transport.

Prices for diesel in transport in CPI and the decarbonisation scenarios reflect the new energy taxation directive as well as different bio-diesel blends. The energy system changes between scenarios cause only limited changes to end-user diesel prices. The strong decline in diesel prices between CPI and decarbonisation scenarios in 2030 reflects oil and product import price savings. This effect is compensated in 2050 by the impact of a significantly higher biofuel penetration in the diesel market.

[17] Average electricity prices in this table relate to a somewhat different customer base compared with electricity prices shown in Part A by including also energy branch customers in addition to those in final demand sectors; this explains the slight differences in average prices (e.g. for 2005 between 109.3 € when including the energy branch and 110.1 € when excluding it).

Table 50: Average EU27 diesel (including blended biodiesel) end –user prices for private transport[18]

		2005	2030	2050
Reference	(EUR(08)/toe)	1271	1877	2250
CPI	% diff. to Reference	0%	20%	16%
Energy Efficiency		0%	3%	17%
Diversified Supply Technology		0%	3%	19%
High RES		0%	3%	21%
Delayed CCS		0%	2%	18%
Low Nuclear		0%	3%	22%

2.8 Conclusions

The Commission services conducted a model-based analysis of decarbonisation scenarios exploring energy consequences of the European Council's objective to reach 80% GHG reductions by 2050 (as compared to 1990), provided that industrialised countries as a group undertake similar efforts. These scenarios explore also the energy security and competitiveness dimension of such energy developments. Businesses as usual projections show only half the GHG emission reductions needed; increased import dependency, in particular for gas; and rising electricity prices and energy costs. Several decarbonisation scenarios highlighting the implications of pursuing each of the four main decarbonisation routes for the energy sector – energy efficiency, renewables, nuclear and CCS - were examined by modelling a high and low end for each of them. The model relies on a series of input assumptions and internal mechanisms to provide the outputs.

The most relevant assumptions and mechanisms of the model

- All scenarios were conducted under the hypothesis that the whole world is acting on climate change which leads to lower demand for fossil fuel prices and subsequently lower prices.
- The model assumes perfect foresight regarding, policy thrust, energy prices and technology developments which assures a very low level of uncertainty for investors, enabling them to make particular cost-effective investment choices without stranded investments. There is also no problem with uncertainty on whether all the infrastructure and other interrelated investment (e.g. grid connections) needed to make a particular investment work will be in place in time.
- Regulatory framework in model allows for investments to be built and costs fully recovered.
- The model assumes a "representative" or average household or consumer while in reality there is a more diversified picture of investors and consumers.
- The model assumes continuous improvements of technologies.

The model-based analysis has shown that decarbonisation of the energy sector is feasible; that it can be achieved through various combinations of energy efficiency, renewables, nuclear and CCS contributions; and that the costs are affordable. The aim of the analysis was not to pick preferred options, a choice that would be surrounded with great uncertainty, but to show some prototype of pathways to decarbonise the energy system while improving energy security and competitiveness and identify common features from scenario analysis.

[18] The average EU price of diesel is calculated with the weighted average of country prices; differences between scenarios are therefore also due to different amounts of diesel used in the countries per scenario; in addition there are different blending ratios; the different taxation regime between the Reference scenario and the other scenarios including CPI reflecting the new proposal for the energy taxation directive.

Common elements to scenario analysis

- There is a need for an integrated approach, e.g.; decarbonisation of heating and transport relies heavily on the availability of decarbonised electricity supply, which in turn depends on very low carbon investments in generation capacity as well as significant grid expansions and smartening.
- Electricity (given its high efficiency and emission free nature at use) makes major inroads in decarbonisation scenarios reaching a 36-39% share in 2050 (almost doubling from current level and becoming the most important final energy source). Decarbonisation in 2050 will require a virtually carbon free electricity sector in the EU, and around 60% CO2 reduction by 2030.
- Significant energy efficiency improvements happen in all decarbonisation scenarios. One unit of GDP in 2050 requires around 70% less energy input compared with 2005. The average annual improvement in energy intensity amounts to around 2.5% pa.
- The share of renewables rises substantially in all scenarios**,** achieving at least 55% in gross final energy consumption in 2050, up 45 percentage points from the current level (a high RES case explores the consequences of raising this share to 75%).
- The increased use of renewable energy as well as energy efficiency improvements require modern, reliable and smart infrastructure including electrical storage.
- Nuclear has a significant role in decarbonisation in Member States where it is accepted, especially if CCS deployment were delayed.
- CCS contributes significantly towards decarbonisation in most scenarios with a particularly strong role in case there were problems with nuclear investment and deployment. Developing CCS can be also seen as an insurance against energy efficiency, RES and nuclear (in some Member States) delivering less or not that quickly.
- All scenarios show a transition from high fuel/operational expenditures to high capital expenditure.
- Substantial changes in the period up to 2030 will be crucial for a cost-efficient long term transition to a decarbonised world[19]. Economic costs are manageable if action starts early so that the restructuring of the energy system goes in parallel with investment cycles thereby avoiding stranded investment as well as costly lock-ins of medium carbon intensive technology.
- The costs of such deep decarbonisation are low in all scenarios given lower fuel procurement costs with cost savings shown mainly in scenarios relying on all four main decarbonisation options.
- Costs are unequally distributed across sectors, with households shouldering the greatest cost increase due to higher costs of direct energy efficiency expenditures in appliances, vehicles and insulation.
- The external EU energy bill for importing oil, gas and coal will be substantially lower under decarbonisation due to substantial reduction in import quantities and prices dependent on global climate action lowering world fossil fuel demand substantially.

When considering these scenario results it might be useful to consider as well that energy supply structures are being transformed. Today we have, for the most part, concentrated rather invisible items, such as mines, import terminals, large power plants outside towns, and underground pipelines for energy dense fossil fuels and nuclear energy. Under decarbonisation we would increasingly have well visible land consuming configurations, such as very large numbers of wind turbines, solar devices, biomass plantation, and additional transmission lines. This might raise issues with **public acceptance** and local opposition.

Deployment of nuclear technologies is fraught with acceptance problems in a large number of Member States. CCS is already now experiencing local opposition in some Member States. Temporary delays in CCS were modelled but not the complete unavailability of this option. Permanent unavailability of CCS could mean that decarbonisation would almost entirely hinge upon very strong progress with RES penetration (and energy efficiency) given the

[19] Scenarios for the Low Carbon Economy Roadmap of March 2011 show the additional costs of delayed action.

existing limitations to nuclear with many Member States having opted out. In the high RES scenario with much energy efficiency (discussed above), the CCS role is very small, given the predominance of RES, requiring in turn large efforts in terms of financing and finding accepted sites for very substantial investments in production and transmission.

Some policy relevant conclusions can be drawn based both on the results of the scenario analysis as well as on a comparison of the hypothetical situation of ideal market and technological conditions needed for modelling purposes and what is found in the much more complex reality.

Implications for future policy making

- Successful decarbonisation while preserving competitiveness of the EU economy is possible. Without global climate action, carbon leakage might be an issue and appropriate instruments could be needed to preserve the competitiveness of energy intensive industries.
- Predictability and stability of policy and regulatory framework creates a favourable environment for low carbon investments. While the regulatory framework to 2020 is mainly given, discussions about policies for 2020-2030 should start now leading to firm decisions that provide certainty for long-term low-carbon investments. Uncertainty can lead to a sub-optimal situation where only investment with low initial capital costs is realised.
- A well functioning internal market is necessary to encourage investment where it is most cost-effective. However, the process of decarbonisation brings new challenges in the context, for example, of. electricity price determination in power exchanges: deep decarbonisation increases substantially the bids based on zero marginal costs leading in many instances to prices rather close to zero, not allowing cost recovery in power generation. Similarly, the necessary expansion and innovation of grids for decarbonisation may be hampered if regulated transmission and distribution focuses on costs minimisation alone. Building of adequate infrastructure needs to be assured and supported either by adequate regulation and/or public funding (e.g. financed by auctioning revenues).
- Energy efficiency tends to show better results in a model than in reality. Energy efficiency improvements are often hampered by split incentives, cash problems of some group of customers; imperfect knowledge and foresight leading to lock-in of some outdated technologies, etc. There is thus a strong need for targeted support policies and public funding supporting more energy efficient consumer choices.
- Strong support should be given to R&D in order to bring down costs of low-carbon technologies.
- Due attention should be given to public acceptance of all low carbon technologies and infrastructure as well willingness of consumers to undertake implied changes and bear higher costs. This will require the engagement of both the public and private sectors early in the process.
- Social policies might need to be considered early in the process given that households shoulder large parts of the costs. While these costs might be affordable by an average household, vulnerable consumers might need specific support to cope with increased expenditures. In addition, transition to a decarbonised economy may involve shifts to more highly skilled jobs, with a possibly difficult adaptation period.
- Flexibility. The future is uncertain and nobody can predict it. That is why preserving flexibility is important for a cost efficient approach, but certain decisions are needed already at this stage in order to start the process that needs innovation and investment, for which investors require a reasonable degree of certainty from reduced policy and regulatory risk.
- External dimension, in particular relations with energy suppliers, should be dealt with pro-actively and at an early stage given the implications of global decarbonisation on fossil fuel export revenues and the necessary production and energy transport investments during the transition phase to decarbonisation; new areas for co-operation could include renewable energy supplies and technology development.

Attachments

ATTACHMENT 1: NUMERICAL RESULTS

1. Reference scenario

EU27: Reference scenario with updated world energy prices														SUMMARY ENERGY BALANCE AND INDICATORS (A)					
ktoe	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**'90-'00**	**'00-'10**	**'10-'20**	**'20-'30**	**'30-'40**	**'40-'50**
														Annual % Change					
Production	**936047**	**950181**	**941860**	**900326**	**844792**	**805284**	**789524**	**780783**	**778102**	**783807**	**795430**	**794964**	**772011**	**0,1**	**-1,1**	**-0,7**	**-0,1**	**0,2**	**-0,3**
Solids	366477	277810	213423	196277	182257	167613	148129	140256	118616	109353	117163	118171	115722	-5,3	-1,6	-2,1	-2,2	-0,1	-0,1
Oil	129551	171052	173006	134290	104398	74104	49136	40242	36706	31989	25325	17092	8469	2,9	-4,9	-7,3	-2,9	-3,6	-10,4
Natural gas	162447	188965	207559	188677	164866	129069	110851	90833	74513	63722	51825	38563	29267	2,5	-2,3	-3,9	-3,9	-3,6	-5,6
Nuclear	202589	223028	243761	257360	238923	239158	222988	231786	247611	268937	283439	298546	294933	1,9	-0,2	-0,7	1,1	1,4	0,4
Renewable energy sources	74984	89326	104111	123722	154349	195340	258420	277667	300657	309806	317677	322592	323620	3,3	4,0	5,3	1,5	0,6	0,2
Hydro	25101	28054	30374	26395	27808	28635	29328	30145	30668	31048	31418	31756	32023	1,9	-0,9	0,5	0,4	0,2	0,2
Biomass & Waste	46473	57201	67982	85129	102433	122385	152662	158880	162784	160925	162098	161497	157972	3,9	4,2	4,1	0,6	0,0	-0,3
Wind	67	350	1913	6061	13850	27580	47984	57378	70750	77239	80764	83535	85243	39,8	21,9	13,2	4,0	1,3	0,5
Solar and others	153	274	421	807	3425	9348	19507	22078	27031	30808	33323	35658	38139	10,7	23,3	19,0	3,3	2,1	1,4
Geothermal	3190	3447	3421	5331	6832	7393	8940	9186	9424	9785	10073	10145	10243	0,7	7,2	2,7	0,5	0,7	0,2
Net Imports	**756079**	**738600**	**826299**	**986048**	**980012**	**1054520**	**1053827**	**1043130**	**1006495**	**1001103**	**1008427**	**1028026**	**1049689**	**0,9**	**1,7**	**0,7**	**-0,5**	**0,0**	**0,4**
Solids	81846	79338	98645	126639	121822	122965	114982	118206	96064	82294	78558	81785	84511	1,9	2,1	-0,6	-1,8	-2,0	0,7
Oil	535645	512185	533039	599851	581600	610760	619288	609026	586837	588234	592904	601403	610189	0,0	0,9	0,6	-0,5	0,1	0,3
- Crude oil and Feedstocks	508460	494000	513725	581995	579010	612729	625088	619901	602209	604393	609655	618641	628328	0,1	1,2	0,8	-0,4	0,1	0,3
- Oil products	27185	18185	19314	17856	2590	-1970	-5800	-10875	-15372	-16159	-16750	-17239	-18140	-3,4	-18,2				
Natural gas	135121	145288	192531	257366	272497	314077	301734	302919	308809	314094	317843	322968	329585	3,6	3,5	1,0	0,2	0,3	0,4
Electricity	3323	1508	1686	971	264	-544	-1754	-1942	-2080	-2327	-2342	-2395	-2487	-6,6	-16,9				
Renewable energy forms	144	279	397	1222	3829	7262	19577	14921	16865	18808	21463	24266	27892	10,7	25,4	17,7	-1,5	2,4	2,7
Gross Inland Consumption	**1660159**	**1662517**	**1723099**	**1825989**	**1774753**	**1807688**	**1790021**	**1769445**	**1728783**	**1728020**	**1746001**	**1764359**	**1762783**	**0,4**	**0,3**	**0,1**	**-0,3**	**0,1**	**0,1**
Solids	452940	364248	321007	319922	304079	290578	263112	258462	214680	191647	195722	199956	200233	-3,4	-0,5	-1,4	-2,0	-0,9	0,2
Oil	631058	650858	658727	676859	635947	632747	615094	594800	567728	563333	560374	559863	559741	0,4	-0,4	-0,3	-0,8	-0,1	0,0
Natural gas	294905	333268	393417	445998	437362	443147	412585	393752	383322	377816	369668	361531	358852	2,9	1,1	-0,6	-0,7	-0,4	-0,3
Nuclear	202589	223028	243761	257360	238923	239158	222988	231786	247611	268937	283439	298546	294933	1,9	-0,2	-0,7	1,1	1,4	0,4
Electricity	3323	1508	1686	971	264	-544	-1754	-1942	-2080	-2327	-2342	-2395	-2487	-6,6	-16,9				
Renewable energy forms	75343	89606	104501	124880	158178	202602	277997	292587	317522	328614	339140	346857	351512	3,3	4,2	5,8	1,3	0,7	0,4
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	17,1	16,1	14,7	14,6	12,4	11,1	11,2	11,3	11,4						
Oil	38,0	39,1	38,2	37,1	35,8	35,0	34,4	33,6	32,8	32,6	32,1	31,7	31,8						
Natural gas	17,8	20,0	22,8	24,4	24,6	24,5	23,0	22,3	22,2	21,9	21,2	20,5	20,4						
Nuclear	12,2	13,4	14,1	14,1	13,5	13,2	12,5	13,1	14,3	15,6	16,2	16,9	16,7						
Renewable energy forms	4,5	5,4	6,1	6,8	8,9	11,2	15,5	16,5	18,4	19,0	19,4	19,7	19,9						
Gross Electricity Generation in GWh_e	**2562823**	**2712209**	**2991720**	**3274121**	**3410155**	**3615644**	**3766750**	**3987027**	**4066714**	**4284467**	**4539591**	**4761463**	**4931154**	**1,6**	**1,3**	**1,0**	**0,8**	**1,1**	**0,8**
Nuclear	794718	881662	944823	997519	926564	928349	871028	920581	995206	1089783	1154633	1246116	1303832	1,7	-0,2	-0,6	1,3	1,5	1,2
Hydro & wind	292648	330306	375545	378836	501839	686819	967260	1108094	1313567	1428648	1500812	1564161	1615455	2,5	2,9	6,8	3,1	1,3	0,7
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1981751	2000476	1928462	1958352	1757941	1766036	1884147	1951186	2011867	1,3	1,7	-0,3	-0,9	0,7	0,7
Fuel Inputs for Thermal Power Generation	**383492**	**362334**	**382613**	**424208**	**434230**	**431464**	**413869**	**417433**	**379617**	**365574**	**374301**	**378407**	**383164**	**0,0**	**1,3**	**-0,5**	**-0,9**	**-0,1**	**0,2**
Solids	263837	230040	223012	229245	232681	220385	196207	193344	154957	135202	139484	143039	143607	-1,7	0,4	-1,7	-2,3	-1,0	0,3
Oil (including refinery gas)	54404	51463	39294	29780	17242	16281	11177	14071	14919	17125	20185	22924	23179	-3,2	-7,9	-4,2	2,9	3,1	1,4
Gas	56754	67806	102408	134637	143444	139931	125482	121522	116857	119958	119786	118254	120825	6,1	3,4	-1,3	-0,7	0,2	0,1
Biomass & Waste	5724	10033	14960	25901	35036	48979	74871	81932	85857	85982	87223	86510	87817	10,1	8,9	7,9	1,4	0,2	0,1
Geothermal heat	2774	2992	2939	4645	5828	5888	6132	6564	7027	7307	7623	7681	7737	0,6	7,1	0,5	1,4	0,8	0,1
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0	0	0	0	0						
Fuel Input in other transformation proc.	**839073**	**814654**	**827098**	**842975**	**794117**	**805120**	**800342**	**784837**	**759949**	**756205**	**754190**	**754073**	**753750**	**-0,1**	**-0,4**	**0,1**	**-0,5**	**-0,1**	**0,0**
Refineries	679426	705954	735244	758152	718853	722167	708598	693191	670478	667636	665791	666042	666769	0,8	-0,2	-0,1	-0,6	-0,1	0,0
Biofuels and hydrogen production	2	202	610	3129	12210	19624	30328	31995	35283	36667	37229	37256	36990	79,6	34,9	9,5	1,5	0,5	-0,1
District heating	32960	23240	19323	16212	15609	15836	15578	15568	13831	13509	12932	11659	11451	-5,2	-2,1	0,0	-1,2	-0,7	-1,2
Others	126685	85258	71921	65482	47445	47493	45838	44083	40357	38392	38238	39115	38540	-5,5	-4,1	-0,3	-1,3	-0,5	0,1
Energy Branch Consumption	**82379**	**88696**	**88176**	**96033**	**92203**	**90715**	**89395**	**88187**	**82583**	**83526**	**87023**	**89342**	**89820**	**0,7**	**0,4**	**-0,3**	**-0,8**	**0,5**	**0,3**
Non-Energy Uses	**97931**	**110541**	**112495**	**117477**	**111512**	**115317**	**117892**	**118700**	**119686**	**120719**	**121626**	**122538**	**123283**	**1,4**	**-0,1**	**0,6**	**0,2**	**0,2**	**0,1**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173676**	**1165873**	**1215397**	**1227169**	**1206870**	**1187036**	**1192289**	**1201689**	**1214718**	**1220944**	**0,4**	**0,5**	**0,5**	**-0,3**	**0,1**	**0,2**
by sector																			
Industry	365650	328513	326949	326308	312402	322907	330271	332209	332530	337637	347017	357606	369219	-1,1	-0,5	0,6	0,1	0,4	0,6
- energy intensive industries	234722	214526	213112	210991	193227	196685	198535	196310	193411	192595	194763	196810	198992	-1,0	-1,0	0,3	-0,3	0,1	0,2
- other industrial sectors	130928	113987	113837	115317	119175	126222	131736	135899	139120	145042	152254	160796	170228	-1,4	0,5	1,0	0,5	0,9	1,1
Residential	264307	280418	286784	308104	308364	320385	317623	303962	299095	296158	293213	292149	288195	0,8	0,7	0,3	-0,6	-0,2	-0,2
Tertiary	158484	160442	159866	176859	175095	182934	181325	176861	173822	175990	178125	180740	180850	0,1	0,9	0,4	-0,4	0,2	0,2
Transport	280269	300617	339389	362405	370012	389172	397950	393838	381589	382505	383333	384224	382680	1,9	0,9	0,7	-0,4	0,0	0,0
by fuel																			
Solids	125031	84977	61454	54486	47419	46274	44102	42716	38479	36813	36731	37803	37714	-6,9	-2,6	-0,7	-1,4	-0,5	0,3
Oil	444429	456959	478882	495857	476505	477401	467526	451334	428648	426107	424509	425057	422388	0,7	0,0	-0,2	-0,9	-0,1	-0,1
Gas	227902	245996	265552	283524	265060	271959	253998	234748	227256	217035	207872	201799	196468	1,5	0,0	-0,4	-1,1	-0,9	-0,6
Electricity	184145	193367	216403	237537	248412	264598	274801	290291	297955	312733	328782	343339	355216	1,6	1,4	1,0	0,8	1,0	0,8
Heat (from CHP and District Heating) (A)	48610	44616	40061	44441	59328	71796	78280	83792	86854	92259	94996	97320	99656	-1,9	4,0	2,8	1,0	0,9	0,5
Other	38592	44073	50640	57832	69149	83367	108462	103990	107845	107343	108800	109399	109503	2,8	3,2	4,6	-0,1	0,1	0,1
CO_2 Emissions (Mt of CO_2 - sec approach)	**4030,6**	**3800,1**	**3810,6**	**3946,6**	**3771,6**	**3713,4**	**3442,0**	**3273,4**	**2982,8**	**2755,5**	**2565,5**	**2451,4**	**2400,4**	**-0,6**	**-0,1**	**-0,9**	**-1,4**	**-1,5**	**-0,7**
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1365,6	1304,8	1124,2	1066,8	890,6	715,2	561,6	463,8	434,0	-1,2	0,3	-1,9	-2,3	-4,5	-2,5
Energy Branch	152,2	171,0	170,2	181,6	157,3	146,0	135,6	124,4	113,8	100,4	90,6	79,7	78,9	1,1	-0,8	-1,5	-1,7	-2,3	-1,4
Industry	781,4	678,1	623,0	581,9	490,5	475,1	459,1	440,7	420,4	407,6	406,5	416,3	424,8	-2,2	-2,4	-0,7	-0,9	-0,3	0,4
Residential	499,4	481,6	466,2	486,7	465,3	465,8	426,2	382,4	361,1	345,6	328,0	315,3	297,5	-0,7	0,0	-0,9	-1,6	-1,0	-1,0
Tertiary	300,5	275,3	242,0	262,2	244,5	238,3	220,3	200,5	187,2	179,0	170,5	165,5	158,3	-2,1	0,1	-1,0	-1,6	-0,9	-0,7
Transport	812,7	872,9	988,5	1053,1	1048,3	1083,3	1076,7	1058,5	1009,7	1007,7	1008,3	1010,7	1007,0	2,0	0,6	0,3	-0,6	0,0	0,0
CO_2 Emissions Index (1990=100)	**100,0**	**94,3**	**94,5**	**97,9**	**93,6**	**92,1**	**85,4**	**81,2**	**74,0**	**68,4**	**63,7**	**60,8**	**59,6**						
CO_2 Emissions (Mt of CO_2 - ref approach)	**4172,0**	**3950,7**	**3922,7**	**4087,6**	**3837,5**	**3780,3**	**3511,3**	**3342,5**	**3053,6**	**2824,8**	**2632,9**	**2516,8**	**2470,2**	**-0,6**	**-0,2**	**-0,9**	**-1,4**	**-1,5**	**-0,6**

EU27: Reference scenario with updated world energy prices | **SUMMARY ENERGY BALANCE AND INDICATORS (B)**

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12750,3	14164,0	15503,7	16824,7	18157,1	19527,9	21002,9	22560,0	2,2	1,2	2,2	1,7	1,5	1,5
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	155,9	141,8	126,4	114,1	102,8	95,2	89,4	84,0	78,1	-1,8	-0,9	-2,1	-2,0	-1,4	-1,3
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,55	3,56	3,48	3,42	3,32	3,32	3,36	3,40	3,42	0,1	-0,1	-0,2	-0,5	0,1	0,2
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6829	7121	7331	7700	7821	8229	8728	9186	9569	1,3	0,9	0,7	0,7	1,1	0,9
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,13	2,05	1,92	1,85	1,73	1,59	1,47	1,39	1,36	-0,9	-0,4	-1,0	-1,1	-1,6	-0,8
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,55	7,31	6,70	6,32	5,74	5,29	4,93	4,73	4,66	-0,8	-0,5	-1,2	-1,5	-1,5	-0,6
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	331,3	291,2	243,0	211,1	177,3	151,8	131,4	116,7	106,4	-2,7	-1,3	-3,1	-3,1	-3,0	-2,1
Import Dependency %	44,6	43,5	46,8	52,5	53,7	56,7	57,2	57,2	56,4	56,1	55,9	56,4	57,6						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	90,3	84,6	78,3	72,4	67,4	63,7	61,2	59,0	57,0	-2,6	-1,0	-1,4	-1,5	-1,0	-0,7
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,9	89,5	80,3	70,9	64,8	58,8	54,3	50,0	46,2	-1,3	-0,3	-1,9	-2,1	-1,8	-1,6
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	94,7	87,5	77,8	69,0	62,2	58,3	54,6	51,3	47,6	-2,3	-0,5	-1,9	-2,2	-1,3	-1,4
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	90,9	83,7	75,7	67,5	62,7	58,5	54,5	50,5	-0,2	-0,3	-1,4	-2,1	-1,4	-1,4
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,32	0,28	0,23	0,21	0,17	0,13	0,10	0,08	0,07	-2,1	-1,5	-3,3	-3,0	-5,5	-3,3
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,93	1,86	1,78	1,73	1,67	1,63	1,59	1,57	1,55	-0,7	-0,8	-0,8	-0,6	-0,5	-0,3
Industry	2,14	2,06	1,91	1,78	1,57	1,47	1,39	1,33	1,26	1,21	1,17	1,16	1,15	-1,1	-1,9	-1,2	-0,9	-0,8	-0,2
Residential	1,89	1,72	1,63	1,58	1,51	1,45	1,34	1,26	1,21	1,17	1,12	1,08	1,03	-1,5	-0,7	-1,2	-1,1	-0,8	-0,8
Tertiary	1,90	1,72	1,51	1,48	1,40	1,30	1,21	1,13	1,08	1,02	0,96	0,92	0,88	-2,2	-0,8	-1,4	-1,2	-1,2	-0,9
Transport	2,90	2,90	2,91	2,91	2,83	2,78	2,71	2,69	2,65	2,63	2,63	2,63	2,63	0,0	-0,3	-0,5	-0,2	-0,1	0,0
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654125**	**715732**	**820281**	**920809**	**1018597**	**1069239**	**1162174**	**1238790**	**1314335**	**1391288**	**1454012**		**2,3**	**2,2**	**1,3**	**1,2**	**1,0**
Nuclear energy			133923	134409	127038	126752	124429	117209	127795	136577	142452	153196	160858		-0,5	-0,2	0,3	1,1	1,2
Renewable energy			112878	147262	209088	280972	400578	455824	541519	589897	622197	652622	680536		6,4	6,7	3,1	1,4	0,9
Hydro (pumping excluded)			99714	104505	107315	110842	114160	115738	117577	119002	119221	120141	121342		0,7	0,6	0,3	0,1	0,2
Wind			12793	40584	86217	141700	231311	269594	325287	350074	364179	375326	382452		21,0	10,4	3,5	1,1	0,5
Solar			371	2172	15307	27855	53437	67626	94508	116353	133969	151728	170533		45,1	13,3	5,9	3,6	2,4
Other renewables (tidal etc.)			0	1	249	575	1671	2866	4146	4468	4828	5427	6209			21,0	9,5	1,5	2,5
Thermal power			407324	434061	484156	513084	493590	496206	492860	512315	549685	585469	612618		1,7	0,2	0,0	1,1	1,1
of which cogeneration units			75917	85934	100379	114000	119045	126780	134574	154672	172095	191977	205866		2,8	1,7	1,2	2,5	1,8
of which CCS units			0	0	0	0	5394	10402	11430	26581	59417	86779	100632				7,8	17,9	5,4
Solids fired			194165	186620	183811	182974	165025	149886	133605	127041	135136	133954	130555		-0,5	-1,1	-2,1	0,1	-0,3
Gas fired			129444	167173	219327	238701	230438	228610	238767	264227	272783	259334	225849		5,4	0,5	0,4	1,3	-1,9
Oil fired			71058	62082	56064	48367	37993	49411	47586	46700	62480	108459	168042		-2,3	-3,8	2,3	2,8	10,4
Biomass-waste fired			12051	17502	24170	42257	59315	67422	71964	73373	78271	82698	87142		7,2	9,4	2,0	0,8	1,1
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	684	783	786	818	876	937	974	1016	1024	1031		2,6	0,4	1,4	0,8	0,1
Load factor for net electric capacities (%)			49,1	49,1	45,1	42,8	40,3	40,5	38,1	37,6	37,2	36,6	36,3						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,2	39,9	40,1	40,3	39,8	41,5	43,3	44,3	45,2						
CHP indicator (% of electricity from CHP)			11,4	11,7	15,0	17,9	18,6	18,6	18,5	21,3	21,9	22,8	23,5						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	1,4	2,7	2,9	6,2	12,4	16,6	17,8						
Non fossil fuels in electricity generation (%)			45,8	44,8	45,9	49,9	56,4	58,8	65,0	66,8	66,4	66,6	66,7						
- nuclear			31,6	30,5	27,2	25,7	23,1	23,1	24,5	25,4	25,4	26,2	26,4						
- renewable energy forms and industrial waste			14,2	14,3	18,7	24,2	33,3	35,8	40,5	41,3	40,9	40,4	40,3						
Indicators for renewables (excluding industrial waste) (%) (B)																			
RES in gross final energy demand (%)			7,6	8,6	11,4	14,6	20,1	21,5	23,9	24,5	25,0	25,1	25,5						
RES in transport (%)			0,5	1,4	4,3	6,6	10,1	10,9	12,5	13,1	13,2	13,3	13,2						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**7160,9**	**7652,0**	**8090,4**	**8495,8**	**8838,1**	**9131,6**	**9385,8**	**9576,4**	**1,9**	**1,0**	**1,6**	**1,1**	**0,7**	**0,5**
Public road transport	544,0	504,0	517,6	526,0	545,0	575,5	602,9	625,6	644,1	659,4	672,1	682,2	689,3	-0,5	0,5	1,0	0,7	0,4	0,3
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,1	5315,2	5614,5	5864,7	6095,9	6299,9	6458,0	6587,0	6663,3	2,4	0,9	1,4	0,8	0,6	0,3
Rail	472,5	421,7	447,9	461,0	482,5	525,4	566,7	607,0	643,6	679,8	715,3	745,7	769,2	-0,5	0,7	1,6	1,3	1,1	0,7
Aviation	317,3	351,3	456,9	527,3	576,9	702,4	824,1	947,9	1065,7	1151,6	1237,8	1321,7	1404,7	3,7	2,4	3,6	2,6	1,5	1,3
Inland navigation	45,8	44,4	41,7	39,5	40,8	42,4	43,9	45,2	46,5	47,5	48,4	49,2	49,8	-0,9	-0,2	0,7	0,6	0,4	0,3
Travel per person (km per capita)	10376	11127	12248	12756	13039	14104	14892	15624	16340	16975	17557	18107	18584	1,7	0,6	1,3	0,9	0,7	0,6
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2972,7**	**3167,8**	**3339,1**	**3487,1**	**3618,9**	**3740,3**	**3843,7**	**3918,4**	**1,7**	**1,9**	**1,8**	**1,0**	**0,7**	**0,5**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2184,8	2325,3	2451,7	2563,8	2663,3	2755,5	2836,0	2892,9	3,7	2,5	1,8	1,0	0,7	0,5
Rail	526,3	386,1	403,7	414,1	440,5	489,1	526,4	556,0	579,8	601,7	622,4	639,1	653,6	-2,6	0,9	1,8	1,0	0,7	0,5
Inland navigation	261,6	267,6	273,3	280,2	281,9	298,8	316,1	331,3	343,5	354,0	362,4	368,5	371,9	0,4	0,3	1,2	0,8	0,5	0,3
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	233	224	215	207	199	192	183	174	-0,4	0,7	-0,4	-0,8	-0,8	-1,0
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**370012**	**389172**	**397950**	**393838**	**381589**	**382505**	**383333**	**384224**	**382680**	**1,9**	**0,9**	**0,7**	**-0,4**	**0,0**	**0,0**
Public road transport	5197	4732	4914	5039	5182	5328	5313	5219	5085	5073	5039	4895	4702	-0,6	0,5	0,2	-0,4	-0,1	-0,7
Private cars and motorcycles	154395	166321	182974	187736	186451	185653	183670	175456	165143	162006	159567	156684	154057	1,7	0,2	-0,2	-1,1	-0,3	-0,4
Trucks	74969	79037	90951	105104	111606	124230	128407	130491	130086	132613	135058	136789	138085	2,0	2,1	1,4	0,1	0,4	0,2
Rail	9560	9452	9600	9436	9598	10162	10028	9697	8529	8431	8552	8598	8579	0,0	0,0	0,4	-1,6	0,0	0,0
Aviation	29038	34112	45395	49703	51709	58103	64570	66757	66345	67834	68452	70517	70495	4,6	1,3	2,2	0,3	0,3	0,3
Inland navigation	7110	6963	5555	5386	5466	5695	5964	6218	6400	6547	6666	6740	6762	-2,4	-0,2	0,9	0,7	0,4	0,1
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	35,3	33,7	31,1	28,4	27,1	26,0	25,2	24,4	0,2	-0,6	-1,2	-1,7	-0,9	-0,6
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,1	45,8	44,3	42,6	40,4	39,6	39,0	38,4	38,1	-0,2	-0,1	-0,4	-0,9	-0,3	-0,2

Reference scenario with Low energy import prices

EU27: Reference scenario with low world energy prices														SUMMARY ENERGY BALANCE AND INDICATORS (A)					
ktoe	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**'90-'00**	**'00-'10**	**'10-'20**	**'20-'30**	**'30-'40**	**'40-'50**
														Annual % Change					
Production	**936047**	**950181**	**941860**	**900326**	**844956**	**806743**	**774724**	**751351**	**744210**	**744394**	**741954**	**734990**	**708730**	**0,1**	**-1,1**	**-0,9**	**-0,4**	**0,0**	**-0,5**
Solids	366477	277810	213423	196277	182280	164596	141188	132111	109418	97710	98461	96608	94609	-5,3	-1,6	-2,5	-2,5	-1,0	-0,4
Oil	129551	171052	173006	134290	104398	72796	47932	39066	35740	30959	24367	16344	8048	2,9	-4,9	-7,5	-2,9	-3,8	-10,5
Natural gas	162447	188965	207559	188677	164866	128886	110612	89928	74766	63734	51574	37757	28571	2,5	-2,3	-3,9	-3,8	-3,6	-5,7
Nuclear	202589	223028	243761	257360	238969	238621	211913	219161	233511	255202	264660	280156	273839	1,9	-0,2	-1,2	1,0	1,3	0,3
Renewable energy sources	74984	89326	104111	123722	154443	201844	263080	271084	290775	296788	302892	304123	303663	3,3	4,0	5,5	1,0	0,4	0,0
Hydro	25101	28054	30374	26395	27808	28667	29384	30172	30686	31046	31438	31763	32030	1,9	-0,9	0,6	0,4	0,2	0,2
Biomass & Waste	46473	57201	67982	85129	102533	125584	154190	153488	156021	151788	151961	148643	144551	3,9	4,2	4,2	0,1	-0,3	-0,5
Wind	67	350	1913	6061	13850	28183	49055	56866	68578	74921	77976	80382	81533	39,8	21,9	13,5	3,4	1,3	0,4
Solar and others	153	274	421	807	3421	11577	21121	21807	26354	29679	31944	33731	35899	10,7	23,3	20,0	2,2	1,9	1,2
Geothermal	3190	3447	3421	5331	6831	7832	9330	8752	9136	9354	9573	9604	9650	0,7	7,2	3,2	-0,2	0,5	0,1
Net Imports	**756079**	**738600**	**826299**	**986048**	**980090**	**1051609**	**1078844**	**1098644**	**1060765**	**1072010**	**1100097**	**1131483**	**1165250**	**0,9**	**1,7**	**1,0**	**-0,2**	**0,4**	**0,6**
Solids	81846	79338	98645	126639	122164	116566	105939	117078	90957	81132	82882	84342	89999	1,9	2,2	-1,4	-1,5	-0,9	0,8
Oil	535645	512185	533039	599851	581355	597240	616521	612915	587072	593828	607030	620899	640530	0,0	0,9	0,6	-0,5	0,3	0,5
- Crude oil and Feedstocks	508460	494000	513725	581995	578837	602248	623376	623292	602837	609643	622423	636129	655377	0,1	1,2	0,7	-0,3	0,3	0,5
- Oil products	27185	18185	19314	17856	2517	-5008	-6855	-10377	-15765	-15815	-15393	-15230	-14846	-3,4	-18,4				
Natural gas	135121	145288	192531	257366	272452	329264	337551	356119	368775	381532	392415	406919	412529	3,6	3,5	2,2	0,9	0,6	0,5
Electricity	3323	1508	1686	971	264	-544	-1754	-1942	-2080	-2327	-2342	-2395	-2487	-6,6	-16,9				
Renewable energy forms	144	279	397	1222	3856	9083	20587	14474	16042	17845	20112	21719	24679	10,7	25,5	18,2	-2,5	2,3	2,1
Gross Inland Consumption	**1660159**	**1662517**	**1723099**	**1825989**	**1774995**	**1806264**	**1799631**	**1794481**	**1748222**	**1758104**	**1782256**	**1805519**	**1812059**	**0,4**	**0,3**	**0,1**	**-0,3**	**0,2**	**0,2**
Solids	452940	364248	321007	319922	304443	281163	247127	249190	200375	178842	181343	180950	184608	-3,4	-0,5	-2,1	-2,1	-1,0	0,2
Oil	631058	650858	658727	676859	635701	617947	610515	596467	566059	566488	571602	576289	586657	0,4	-0,4	-0,4	-0,8	0,1	0,3
Natural gas	294905	333268	393417	445998	437318	458150	448164	446048	443541	445266	443990	444676	441099	2,9	1,1	0,2	-0,1	0,0	-0,1
Nuclear	202589	223028	243761	257360	238969	238621	211913	219161	233511	255202	264660	280156	273839	1,9	-0,2	-1,2	1,0	1,3	0,3
Electricity	3323	1508	1686	971	264	-544	-1754	-1942	-2080	-2327	-2342	-2395	-2487	-6,6	-16,9				
Renewable energy forms	75343	89606	104501	124880	158300	210927	283667	285558	306817	314633	323004	325842	328343	3,3	4,2	6,0	0,8	0,5	0,2
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	17,2	15,6	13,7	13,9	11,5	10,2	10,2	10,0	10,2						
Oil	38,0	39,1	38,2	37,1	35,8	34,2	33,9	33,2	32,4	32,2	32,1	31,9	32,4						
Natural gas	17,8	20,0	22,8	24,4	24,6	25,4	24,9	24,9	25,4	25,3	24,9	24,6	24,3						
Nuclear	12,2	13,4	14,1	14,1	13,5	13,2	11,8	12,2	13,4	14,5	14,8	15,5	15,1						
Renewable energy forms	4,5	5,4	6,1	6,8	8,9	11,7	15,8	15,9	17,6	17,9	18,1	18,0	18,1						
Gross Electricity Generation in GWh_e	**2562823**	**2712209**	**2991720**	**3274121**	**3409540**	**3579990**	**3696830**	**3910011**	**4002791**	**4206235**	**4459038**	**4677810**	**4840859**	**1,6**	**1,3**	**0,8**	**0,8**	**1,1**	**0,8**
Nuclear	794718	881662	944823	997519	926744	926184	827462	867959	937530	1033820	1076501	1167142	1206811	1,7	-0,2	-1,1	1,3	1,4	1,1
Hydro & wind	292648	330306	375545	378836	501839	694261	986726	1108021	1289057	1400094	1465847	1519821	1561038	2,5	2,9	7,0	2,7	1,3	0,6
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1980957	1959545	1882642	1934031	1776205	1772322	1916691	1990847	2073010	1,3	1,7	-0,5	-0,6	0,8	0,8
Fuel Inputs for Thermal Power Generation	**383492**	**362334**	**382613**	**424208**	**433918**	**421402**	**402095**	**411216**	**376607**	**364739**	**375750**	**379562**	**387716**	**0,0**	**1,3**	**-0,8**	**-0,7**	**0,0**	**0,3**
Solids	263837	230040	223012	229245	232690	210625	177884	179755	136173	118027	121339	120857	125456	-1,7	0,4	-2,7	-2,6	-1,1	0,3
Oil (including refinery gas)	54404	51463	39294	29780	17274	13069	9463	11650	14063	17353	20001	22883	23246	-3,2	-7,9	-5,8	4,0	3,6	1,5
Gas	56754	67806	102408	134637	142867	140128	130086	130096	132413	132211	131843	133444	135557	6,1	3,4	-0,9	0,2	0,0	0,3
Biomass & Waste	5724	10033	14960	25901	35260	51578	78413	83034	86815	89750	94852	94605	95629	10,1	9,0	8,3	1,0	0,9	0,1
Geothermal heat	2774	2992	2939	4645	5828	6002	6248	6680	7142	7399	7714	7772	7828	0,6	7,1	0,7	1,3	0,8	0,1
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0	0	0	0	0						
Fuel Input in other transformation proc.	**839073**	**814654**	**827098**	**842975**	**793957**	**795764**	**800355**	**789915**	**760997**	**760282**	**765231**	**768953**	**776720**	**-0,1**	**-0,4**	**0,1**	**-0,5**	**0,1**	**0,1**
Refineries	679426	705954	735244	758152	718673	709499	704546	694320	668973	670763	676613	681957	693075	0,8	-0,2	-0,2	-0,5	0,1	0,2
Biofuels and hydrogen production	2	202	610	3129	12210	22098	31041	30036	32808	32930	31851	30343	28482	79,6	34,9	9,8	0,6	-0,3	-1,1
District heating	32960	23240	19323	16212	15391	16282	16195	16766	13946	12649	12385	11718	11220	-5,2	-2,2	0,5	-1,5	-1,2	-1,0
Others	126685	85258	71921	65482	47683	47885	48573	48793	45270	43940	44382	44935	43944	-5,5	-4,0	0,2	-0,7	-0,2	-0,1
Energy Branch Consumption	**82379**	**88696**	**88176**	**96033**	**92073**	**90331**	**89465**	**88531**	**82892**	**83756**	**87792**	**90666**	**92099**	**0,7**	**0,4**	**-0,3**	**-0,8**	**0,6**	**0,5**
Non-Energy Uses	**97931**	**110541**	**112495**	**117477**	**111488**	**115337**	**118650**	**120217**	**121239**	**122827**	**124273**	**125527**	**126852**	**1,4**	**-0,1**	**0,6**	**0,2**	**0,2**	**0,2**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173676**	**1165917**	**1220192**	**1249573**	**1240531**	**1215419**	**1227393**	**1243913**	**1260655**	**1271891**	**0,4**	**0,5**	**0,7**	**-0,3**	**0,2**	**0,2**
by sector																			
Industry	365650	328513	326949	326308	312454	324447	333795	338272	339167	345310	354837	365648	377451	-1,1	-0,5	0,7	0,2	0,5	0,6
- energy intensive industries	234722	214526	213112	210991	193330	197669	201270	201148	198722	198885	201189	203183	205315	-1,0	-1,0	0,4	-0,1	0,1	0,2
- other industrial sectors	130928	113987	113837	115317	119124	126778	132525	137124	140445	146425	153648	162465	172136	-1,4	0,5	1,1	0,6	0,9	1,1
Residential	264307	280418	286784	308104	308342	323961	327748	318361	313344	312171	310506	309942	305872	0,8	0,7	0,6	-0,4	-0,1	-0,2
Tertiary	158484	160442	159866	176859	175109	183861	185722	185006	181447	185957	189860	193857	194991	0,1	0,9	0,6	-0,2	0,5	0,3
Transport	280269	300617	339389	362405	370012	387924	402308	398891	381461	383956	388710	391208	393577	1,9	0,9	0,8	-0,5	0,2	0,1
by fuel																			
Solids	125031	84977	61454	54486	47716	45211	43809	43651	39646	37714	37400	37901	37314	-6,9	-2,5	-0,9	-1,0	-0,6	0,0
Oil	444429	456959	478882	495857	476263	468996	467417	457110	429572	431142	436619	441663	447464	0,7	-0,1	-0,2	-0,8	0,2	0,2
Gas	227902	245996	265552	283524	265632	284726	282238	274985	269218	267413	263648	260587	256524	1,5	0,0	0,6	-0,5	-0,2	-0,3
Electricity	184145	193367	216403	237537	248325	262052	269809	284714	293227	307051	322625	336298	347174	1,6	1,4	0,8	0,8	1,0	0,7
Heat (from CHP and District Heating) [(A)]	48610	44616	40061	44441	58782	70830	77358	83767	84875	89632	91077	92866	93819	-1,9	3,9	2,8	0,9	0,7	0,3
Other	38592	44073	50640	57832	69199	88377	108942	96302	98882	94442	92544	91340	89596	2,8	3,2	4,6	-1,0	-0,7	-0,3
CO_2 Emissions (Mt of CO_2 - sec approach)	**4030,6**	**3800,1**	**3810,6**	**3946,6**	**3772,2**	**3666,1**	**3442,2**	**3356,5**	**3051,9**	**2871,4**	**2705,7**	**2587,3**	**2556,8**	**-0,6**	**-0,1**	**-0,9**	**-1,2**	**-1,2**	**-0,6**
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1364,1	1258,9	1057,7	1028,7	847,8	683,4	517,4	394,4	360,5	-1,2	0,3	-2,5	-2,2	-4,8	-3,5
Energy Branch	152,2	171,0	170,2	181,6	157,4	143,8	136,5	128,2	117,6	108,5	102,6	97,2	95,3	1,1	-0,8	-1,4	-1,5	-1,4	-0,7
Industry	781,4	678,1	623,0	581,9	492,9	482,0	478,6	472,9	459,9	455,9	460,2	470,0	483,0	-2,2	-2,3	-0,3	-0,4	0,0	0,5
Residential	499,4	481,6	466,2	486,7	465,1	470,5	451,4	426,8	405,2	397,8	386,0	375,5	359,0	-0,7	0,0	-0,3	-1,1	-0,5	-0,7
Tertiary	300,5	275,3	242,0	262,2	244,3	238,8	230,7	220,2	204,3	202,2	198,7	197,4	193,5	-2,1	0,1	-0,6	-1,2	-0,3	-0,3
Transport	812,7	872,9	988,5	1053,1	1048,3	1072,0	1087,3	1079,6	1017,1	1023,6	1040,8	1052,7	1065,6	2,0	0,6	0,4	-0,7	0,2	0,2
CO_2 Emissions Index (1990=100)	**100,0**	**94,3**	**94,5**	**97,9**	**93,6**	**91,0**	**85,4**	**83,3**	**75,7**	**71,2**	**67,1**	**64,2**	**63,4**						
CO_2 Emissions (Mt of CO_2 - ref approach)	**4172,0**	**3950,7**	**3922,7**	**4087,6**	**3838,2**	**3737,7**	**3519,7**	**3433,5**	**3131,3**	**2949,5**	**2782,0**	**2661,6**	**2634,4**	**-0,6**	**-0,2**	**-0,9**	**-1,2**	**-1,2**	**-0,5**

EU27: Reference scenario with low world energy prices														SUMMARY ENERGY BALANCE AND INDICATORS (B)					
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12750,3	14164,0	15503,7	16824,7	18157,1	19527,9	21002,9	22560,0	2,2	1,2	2,2	1,7	1,5	1,5
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	155,9	141,7	127,1	115,7	103,9	96,8	91,3	86,0	80,3	-1,8	-0,9	-2,0	-2,0	-1,3	-1,3
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,55	3,56	3,50	3,47	3,36	3,38	3,43	3,48	3,52	0,1	-0,1	-0,1	-0,4	0,2	0,3
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6827	7051	7195	7551	7699	8079	8573	9024	9394	1,3	0,9	0,5	0,7	1,1	0,9
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,13	2,03	1,91	1,87	1,75	1,63	1,52	1,43	1,41	-0,9	-0,4	-1,0	-0,9	-1,4	-0,7
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,55	7,22	6,70	6,48	5,87	5,52	5,20	4,99	4,96	-0,8	-0,5	-1,2	-1,3	-1,2	-0,5
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	331,3	287,5	243,0	216,5	181,4	158,1	138,6	123,2	113,3	-2,7	-1,3	-3,1	-2,9	-2,7	-2,0
Import Dependency %	44,6	43,5	46,8	52,5	53,7	56,6	58,2	59,4	58,8	59,0	59,7	60,6	62,2						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	90,3	85,0	79,2	73,8	68,8	65,2	62,6	60,3	58,3	-2,6	-1,0	-1,3	-1,4	-0,9	-0,7
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,9	90,5	82,8	74,3	67,9	62,0	57,5	53,0	49,0	-1,3	-0,3	-1,6	-2,0	-1,6	-1,6
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	94,7	88,0	79,7	72,2	65,0	61,6	58,2	55,0	51,3	-2,3	-0,5	-1,7	-2,0	-1,1	-1,3
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	90,6	84,6	76,6	67,5	63,0	59,3	55,5	52,0	-0,2	-0,3	-1,3	-2,2	-1,3	-1,3
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,32	0,27	0,22	0,20	0,16	0,13	0,09	0,07	0,06	-2,1	-1,5	-3,7	-2,9	-5,8	-4,2
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,93	1,85	1,80	1,77	1,72	1,69	1,68	1,66	1,65	-0,7	-0,8	-0,7	-0,5	-0,2	-0,1
Industry	2,14	2,06	1,91	1,78	1,58	1,49	1,43	1,40	1,36	1,32	1,30	1,29	1,28	-1,1	-1,9	-1,0	-0,6	-0,4	-0,1
Residential	1,89	1,72	1,63	1,58	1,51	1,45	1,38	1,34	1,29	1,27	1,24	1,21	1,17	-1,5	-0,7	-0,9	-0,6	-0,4	-0,6
Tertiary	1,90	1,72	1,51	1,48	1,40	1,30	1,24	1,19	1,13	1,09	1,05	1,02	0,99	-2,2	-0,8	-1,2	-1,0	-0,7	-0,5
Transport	2,90	2,90	2,91	2,91	2,83	2,76	2,70	2,71	2,67	2,67	2,68	2,69	2,71	0,0	-0,3	-0,5	-0,1	0,0	0,1
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654125**	**715732**	**820280**	**921348**	**1023474**	**1056112**	**1142278**	**1217909**	**1289022**	**1363389**	**1420771**		**2,3**	**2,2**	**1,1**	**1,2**	**1,0**
Nuclear energy			133923	134409	127038	126752	123686	112747	120786	129753	132911	142885	148596		-0,5	-0,3	-0,2	1,0	1,1
Renewable energy			112878	147262	209088	283884	411814	459889	534502	580889	610823	637242	661705		6,4	7,0	2,6	1,3	0,8
Hydro (pumping excluded)			99714	104505	107315	110988	114516	115937	117729	119058	119329	120119	121318		0,7	0,7	0,3	0,1	0,2
Wind			12793	40584	86217	144412	236694	268564	316027	340123	352348	362424	368159		21,0	10,6	2,9	1,1	0,4
Solar			371	2172	15307	27909	58929	72536	96607	117366	134433	149503	166320		45,1	14,4	5,1	3,4	2,2
Other renewables (tidal etc.)			0	1	249	575	1675	2851	4139	4343	4713	5195	5909			21,0	9,5	1,3	2,3
Thermal power			407324	434061	484154	510712	487974	483476	486990	507267	545287	583263	610470		1,7	0,1	0,0	1,1	1,1
of which cogeneration units			76231	85773	100282	113030	117658	126719	132441	146772	158341	177742	194205		2,8	1,6	1,2	1,8	2,1
of which CCS units			0	0	0	0	5394	10547	12181	27806	64438	102927	122123				8,5	18,1	6,6
Solids fired			194165	186620	183751	182050	160820	142964	126571	116771	122803	117902	115620		-0,5	-1,3	-2,4	-0,3	-0,6
Gas fired			129444	167173	219380	238037	229889	229407	244098	272068	281696	277550	245965		5,4	0,5	0,6	1,4	-1,3
Oil fired			71058	62082	56075	45479	34571	41608	42386	42493	59561	101212	157275		-2,3	-4,7	2,1	3,5	10,2
Biomass-waste fired			12051	17502	24165	44345	61860	68606	72982	74948	80199	85563	90566		7,2	9,9	1,7	0,9	1,2
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	684	783	801	834	891	952	986	1028	1036	1043		2,6	0,6	1,3	0,8	0,1
Load factor for net electric capacities (%)			49,1	49,1	45,1	42,3	39,4	40,2	38,2	37,6	37,2	36,7	36,3						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,3	40,0	40,3	40,4	40,6	41,8	43,9	45,1	46,0						
CHP indicator (% of electricity from CHP)			11,4	11,7	15,0	17,9	18,7	19,0	18,9	20,6	21,1	21,7	22,1						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	1,5	2,9	3,1	6,4	13,4	19,4	21,5						
Non fossil fuels in electricity generation (%)			45,8	44,8	45,9	50,8	57,1	58,7	64,1	66,3	65,7	65,8	65,6						
- nuclear			31,6	30,5	27,2	25,9	22,4	22,2	23,4	24,6	24,1	25,0	24,9						
- renewable energy forms and industrial waste			14,2	14,3	18,8	24,9	34,8	36,5	40,6	41,8	41,6	40,9	40,6						
Indicators for renewables (excluding industrial waste) (%) [(B)]																			
RES in gross final energy demand (%)			7,6	8,6	11,4	15,2	20,2	20,4	22,5	22,9	23,2	23,1	23,2						
RES in transport (%)			0,5	1,4	4,3	7,4	10,3	10,3	11,9	11,9	11,5	11,0	10,3						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**7140,9**	**7690,4**	**8182,1**	**8580,0**	**8972,1**	**9321,7**	**9617,5**	**9879,6**	**1,9**	**1,0**	**1,7**	**1,1**	**0,8**	**0,6**
Public road transport	544,0	504,0	517,6	526,0	545,0	574,2	602,4	625,8	644,2	660,1	673,6	684,2	692,3	-0,5	0,5	1,0	0,7	0,4	0,3
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,1	5297,5	5650,2	5949,8	6173,9	6423,4	6632,9	6800,4	6942,1	2,4	0,9	1,5	0,9	0,7	0,5
Rail	472,5	421,7	447,9	461,0	482,5	525,7	567,8	608,7	645,4	682,1	718,3	748,6	772,1	-0,5	0,7	1,6	1,3	1,1	0,7
Aviation	317,3	351,3	456,9	527,3	576,9	701,2	826,2	952,4	1070,1	1158,9	1248,3	1334,9	1423,0	3,7	2,4	3,7	2,6	1,6	1,3
Inland navigation	45,8	44,4	41,7	39,5	40,8	42,3	43,9	45,3	46,5	47,6	48,6	49,4	50,1	-0,9	-0,2	0,7	0,6	0,4	0,3
Travel per person (km per capita)	10376	11127	12248	12756	13039	14065	14967	15801	16502	17232	17923	18554	19172	1,7	0,6	1,4	1,0	0,8	0,7
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2961,6**	**3182,1**	**3379,3**	**3524,0**	**3678,5**	**3826,3**	**3949,6**	**4057,5**	**1,7**	**1,9**	**1,8**	**1,0**	**0,8**	**0,6**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2174,2	2339,1	2490,5	2599,1	2720,7	2838,4	2938,3	3027,8	3,7	2,5	1,9	1,1	0,9	0,6
Rail	526,3	386,1	403,7	414,1	440,5	489,1	526,9	557,0	580,9	603,0	624,1	640,9	655,2	-2,6	0,9	1,8	1,0	0,7	0,5
Inland navigation	261,6	267,6	273,3	280,2	281,9	298,3	316,0	331,8	343,9	354,8	363,8	370,4	374,5	0,4	0,3	1,1	0,8	0,6	0,3
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	232	225	218	209	203	196	188	180	-0,4	0,7	-0,4	-0,7	-0,7	-0,9
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**370012**	**387924**	**402308**	**398891**	**381461**	**383956**	**388710**	**391208**	**393577**	**1,9**	**0,9**	**0,8**	**-0,5**	**0,2**	**0,1**
Public road transport	5197	4732	4914	5039	5182	5319	5311	5226	5090	5082	5053	4936	4768	-0,6	0,5	0,2	-0,4	-0,1	-0,6
Private cars and motorcycles	154395	166321	182974	187736	186451	185094	184719	173681	160250	158300	156630	153803	151794	1,7	0,2	-0,1	-1,4	-0,2	-0,3
Trucks	74969	79037	90951	105104	111606	123709	129281	132593	131836	135348	138852	141269	143835	2,0	2,1	1,5	0,2	0,5	0,4
Rail	9560	9452	9600	9436	9597	10138	10045	9743	8560	8454	8584	8631	8608	0,0	0,0	0,5	-1,6	0,0	0,0
Aviation	29038	34112	45395	49703	51709	57983	66990	71421	69319	70206	72895	75789	77753	4,6	1,3	2,6	0,3	0,5	0,6
Inland navigation	7110	6963	5555	5386	5466	5681	5962	6228	6407	6566	6697	6780	6819	-2,4	-0,2	0,9	0,7	0,4	0,2
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	35,4	34,0	31,1	27,9	26,5	25,6	24,8	24,2	0,2	-0,6	-1,1	-2,0	-0,8	-0,6
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,1	45,7	44,4	42,7	40,4	39,7	39,1	38,6	38,2	-0,2	-0,1	-0,4	-0,9	-0,3	-0,2

Reference scenario with High energy import prices

EU27: Reference scenario with high world energy prices														SUMMARY ENERGY BALANCE AND INDICATORS (A)					
ktoe	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**'90-'00**	**'00-'10**	**'10-'20**	**'20-'30**	**'30-'40**	**'40-'50**
														Annual % Change					
Production	**936047**	**950181**	**941860**	**900326**	**845064**	**817644**	**811737**	**802723**	**806224**	**819143**	**828965**	**830368**	**808009**	**0,1**	**-1,1**	**-0,4**	**-0,1**	**0,3**	**-0,3**
Solids	366477	277810	213423	196277	182270	168669	150313	143980	124519	118672	122786	125237	121804	-5,3	-1,6	-1,9	-1,9	-0,1	-0,1
Oil	129551	171052	173006	134290	104398	76134	50651	41472	37934	32861	26090	17729	8791	2,9	-4,9	-7,0	-2,8	-3,7	-10,3
Natural gas	162447	188965	207559	188677	164866	129314	111043	90249	73816	62450	50163	35926	28407	2,5	-2,3	-3,9	-4,0	-3,8	-5,5
Nuclear	202589	223028	243761	257360	238928	239919	232763	240570	259190	285393	299892	314633	307768	1,9	-0,2	-0,3	1,1	1,5	0,3
Renewable energy sources	74984	89326	104111	123722	154603	203608	266968	286451	310764	319767	330034	336842	341239	3,3	4,0	5,6	1,5	0,6	0,3
Hydro	25101	28054	30374	26395	27809	28656	29340	30157	30709	31057	31432	31770	32037	1,9	-0,9	0,5	0,5	0,2	0,2
Biomass & Waste	46473	57201	67982	85129	102686	129128	158774	165107	169467	166943	168423	168652	165401	3,9	4,2	4,5	0,7	-0,1	-0,2
Wind	67	350	1913	6061	13850	28279	48857	58566	72773	79868	84707	87539	91473	39,8	21,9	13,4	4,1	1,5	0,8
Solar and others	153	274	421	807	3426	9777	20392	22915	27915	31657	34964	38294	41603	10,7	23,3	19,5	3,2	2,3	1,8
Geothermal	3190	3447	3421	5331	6832	7769	9605	9706	9899	10242	10508	10588	10724	0,7	7,2	3,5	0,3	0,6	0,2
Net Imports	**756079**	**738600**	**826299**	**986048**	**979634**	**996340**	**976160**	**969612**	**934871**	**930538**	**939404**	**958614**	**976996**	**0,9**	**1,7**	**0,0**	**-0,4**	**0,0**	**0,4**
Solids	81846	79338	98645	126639	121083	125097	114259	119071	94503	75261	73956	80428	82826	1,9	2,1	-0,6	-1,9	-2,4	1,1
Oil	535645	512185	533039	599851	581740	570199	570016	574724	555108	565209	571220	578921	589646	0,0	0,9	-0,2	-0,3	0,3	0,3
- Crude oil and Feedstocks	508460	494000	513725	581995	579069	582182	587445	593537	577975	587962	594853	603766	614849	0,1	1,2	0,1	-0,2	0,3	0,3
- Oil products	27185	18185	19314	17856	2671	-11983	-17429	-18813	-22867	-22753	-23633	-24845	-25203	-3,4	-18,0				
Natural gas	135121	145288	192531	257366	272703	291744	270028	261629	269564	272811	274291	276043	277755	3,6	3,5	-0,1	0,0	0,2	0,1
Electricity	3323	1508	1686	971	264	-544	-1754	-1942	-2080	-2327	-2342	-2395	-2487	-6,6	-16,9				
Renewable energy forms	144	279	397	1222	3844	9844	23611	16129	17776	19584	22280	25618	29256	10,7	25,5	19,9	-2,8	2,3	2,8
Gross Inland Consumption	**1660159**	**1662517**	**1723099**	**1825989**	**1774646**	**1763688**	**1736895**	**1719762**	**1687461**	**1694492**	**1712132**	**1732055**	**1727780**	**0,4**	**0,3**	**-0,2**	**-0,3**	**0,1**	**0,1**
Solids	452940	364248	321007	319922	303353	293765	264572	263052	219023	193933	196742	205665	204631	-3,4	-0,6	-1,4	-1,9	-1,1	0,4
Oil	631058	650858	658727	676859	636086	596037	569665	563624	539408	542881	541072	539723	541212	0,4	-0,3	-1,1	-0,5	0,0	0,0
Natural gas	294905	333268	393417	445998	437569	421058	381071	351878	343380	335262	324454	311969	306162	2,9	1,1	-1,4	-1,0	-0,6	-0,6
Nuclear	202589	223028	243761	257360	238928	239919	232763	240570	259190	285393	299892	314633	307768	1,9	-0,2	-0,3	1,1	1,5	0,3
Electricity	3323	1508	1686	971	264	-544	-1754	-1942	-2080	-2327	-2342	-2395	-2487	-6,6	-16,9				
Renewable energy forms	75343	89606	104501	124880	158447	213452	290578	302580	328540	339351	352313	362460	370494	3,3	4,3	6,3	1,2	0,7	0,5
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	17,1	16,7	15,2	15,3	13,0	11,4	11,5	11,9	11,8						
Oil	38,0	39,1	38,2	37,1	35,8	33,8	32,8	32,8	32,0	32,0	31,6	31,2	31,3						
Natural gas	17,8	20,0	22,8	24,4	24,7	23,9	21,9	20,5	20,3	19,8	19,0	18,0	17,7						
Nuclear	12,2	13,4	14,1	14,1	13,5	13,6	13,4	14,0	15,4	16,8	17,5	18,2	17,8						
Renewable energy forms	4,5	5,4	6,1	6,8	8,9	12,1	16,7	17,6	19,5	20,0	20,6	20,9	21,4						
Gross Electricity Generation in GWh_e	**2562823**	**2712209**	**2991720**	**3274121**	**3407994**	**3649338**	**3829651**	**4022391**	**4103132**	**4315174**	**4551703**	**4780126**	**4952373**	**1,6**	**1,3**	**1,2**	**0,7**	**1,0**	**0,8**
Nuclear	794718	881662	944823	997519	926585	931441	909499	955534	1042329	1158788	1223333	1317803	1358930	1,7	-0,2	-0,2	1,4	1,6	1,1
Hydro & wind	292648	330306	375545	378836	501843	695188	981856	1126533	1343293	1465093	1561740	1637554	1723986	2,5	2,9	6,9	3,2	1,5	1,0
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1979566	2022709	1938295	1940325	1717510	1691293	1766629	1824769	1869457	1,3	1,7	-0,2	-1,2	0,3	0,6
Fuel Inputs for Thermal Power Generation	**383492**	**362334**	**382613**	**424208**	**433841**	**438221**	**416849**	**417554**	**375542**	**353660**	**356466**	**360088**	**362549**	**0,0**	**1,3**	**-0,4**	**-1,0**	**-0,5**	**0,2**
Solids	263837	230040	223012	229245	232197	226359	203525	204145	165170	141391	143479	150650	149576	-1,7	0,4	-1,3	-2,1	-1,4	0,4
Oil (including refinery gas)	54404	51463	39294	29780	17272	18159	10913	14759	16135	18128	20317	22824	23408	-3,2	-7,9	-4,5	4,0	2,3	1,4
Gas	56754	67806	102408	134637	143441	136528	122263	112413	103910	104935	100885	94232	96430	6,1	3,4	-1,6	-1,6	-0,3	-0,5
Biomass & Waste	5724	10033	14960	25901	35103	51226	73957	79613	83240	81838	84102	84642	85338	10,1	8,9	7,7	1,2	0,1	0,1
Geothermal heat	2774	2992	2939	4645	5828	5948	6192	6624	7087	7367	7683	7741	7796	0,6	7,1	0,6	1,4	0,8	0,1
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0	0	0	0	0						
Fuel Input in other transformation proc.	**839073**	**814654**	**827098**	**842975**	**794172**	**776152**	**761745**	**754684**	**735363**	**739846**	**740552**	**741618**	**742387**	**-0,1**	**-0,4**	**-0,4**	**-0,4**	**0,1**	**0,0**
Refineries	679426	705954	735244	758152	718914	692861	670292	666502	645621	650704	650516	650617	652619	0,8	-0,2	-0,7	-0,4	0,1	0,0
Biofuels and hydrogen production	2	202	610	3129	12210	23763	35550	35146	39958	40788	41351	41636	41566	79,6	34,9	11,3	1,2	0,3	0,1
District heating	32960	23240	19323	16212	15753	15139	15502	14613	14811	14766	14058	13524	13189	-5,2	-2,0	-0,2	-0,5	-0,5	-0,6
Others	126685	85258	71921	65482	47295	44389	40401	38422	34973	33588	34627	35841	35013	-5,5	-4,1	-1,6	-1,4	-0,1	0,1
Energy Branch Consumption	**82379**	**88696**	**88176**	**96033**	**92137**	**87501**	**85947**	**84593**	**79313**	**81018**	**83550**	**85872**	**86160**	**0,7**	**0,4**	**-0,7**	**-0,8**	**0,5**	**0,3**
Non-Energy Uses	**97931**	**110541**	**112495**	**117477**	**111501**	**113287**	**112238**	**113456**	**114233**	**115811**	**116974**	**118021**	**118943**	**1,4**	**-0,1**	**0,1**	**0,2**	**0,2**	**0,2**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173676**	**1165705**	**1174920**	**1175499**	**1160215**	**1146712**	**1160317**	**1171818**	**1186237**	**1192996**	**0,4**	**0,5**	**0,1**	**-0,2**	**0,2**	**0,2**
by sector																			
Industry	365650	328513	326949	326308	312250	318093	322166	323799	324906	331579	341702	353194	364625	-1,1	-0,5	0,3	0,1	0,5	0,7
- energy intensive industries	234722	214526	213112	210991	193108	193323	192248	190048	187681	188143	190297	193252	195353	-1,0	-1,0	0,0	-0,2	0,1	0,3
- other industrial sectors	130928	113987	113837	115317	119142	124770	129918	133752	137225	143435	151406	159943	169272	-1,4	0,5	0,9	0,5	1,0	1,1
Residential	264307	280418	286784	308104	308348	309577	302416	287509	283321	282620	281006	280748	277506	0,8	0,7	-0,2	-0,7	-0,1	-0,1
Tertiary	158484	160442	159866	176859	175094	175481	170920	167882	164661	167797	169952	172634	172323	0,1	0,9	-0,2	-0,4	0,3	0,1
Transport	280269	300617	339389	362405	370013	371769	379996	381024	373824	378321	379157	379661	378542	1,9	0,9	0,3	-0,2	0,1	0,0
by fuel																			
Solids	125031	84977	61454	54486	47150	45242	41185	39623	35511	34847	35271	37068	37325	-6,9	-2,6	-1,3	-1,5	-0,1	0,6
Oil	444429	456959	478882	495857	476489	445159	431408	426242	406172	410602	409732	409357	407578	0,7	-0,1	-1,0	-0,6	0,1	-0,1
Gas	227902	245996	265552	283524	265148	251152	223763	202020	199347	189879	183030	180174	173591	1,5	0,0	-1,7	-1,1	-0,9	-0,5
Electricity	184145	193367	216403	237537	248253	267293	279771	293982	301562	315775	331364	346422	358647	1,6	1,4	1,2	0,8	0,9	0,8
Heat (from CHP and District Heating) (A)	48610	44616	40061	44441	59296	74882	79075	84024	86377	91915	94315	96906	99536	-1,9	4,0	2,9	0,9	0,9	0,5
Other	38592	44073	50640	57832	69369	91192	120297	114324	117742	117298	118106	116311	116319	2,8	3,2	5,7	-0,2	0,0	-0,2
CO_2 Emissions (Mt of CO_2 - sec approach)	**4030,6**	**3800,1**	**3810,6**	**3946,6**	**3769,7**	**3573,0**	**3257,4**	**3163,1**	**2889,4**	**2675,0**	**2503,8**	**2397,4**	**2335,4**	**-0,6**	**-0,1**	**-1,4**	**-1,2**	**-1,4**	**-0,7**
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1364,3	1323,0	1142,1	1130,6	953,1	764,1	617,4	524,3	484,6	-1,2	0,3	-1,8	-1,8	-4,2	-2,4
Energy Branch	152,2	171,0	170,2	181,6	157,6	138,2	126,1	117,1	105,1	91,2	83,5	66,8	63,7	1,1	-0,8	-2,2	-1,8	-2,3	-2,7
Industry	781,4	678,1	623,0	581,9	489,9	449,0	418,1	396,0	382,3	373,3	377,1	396,3	404,9	-2,2	-2,4	-1,6	-0,9	-0,1	0,7
Residential	499,4	481,6	466,2	486,7	465,0	426,5	373,0	331,0	312,8	304,9	291,7	280,8	263,6	-0,7	0,0	-2,2	-1,7	-0,7	-1,0
Tertiary	300,5	275,3	242,0	262,2	244,5	217,6	190,9	177,9	163,8	158,9	150,9	145,4	137,8	-2,1	0,1	-2,4	-1,5	-0,8	-0,9
Transport	812,7	872,9	988,5	1053,1	1048,3	1018,8	1007,2	1010,5	972,2	982,6	983,2	983,8	980,8	2,0	0,6	-0,4	-0,4	0,1	0,0
CO_2 Emissions Index (1990=100)	**100,0**	**94,3**	**94,5**	**97,9**	**93,5**	**88,6**	**80,8**	**78,5**	**71,7**	**66,4**	**62,1**	**59,5**	**57,9**						
CO_2 Emissions (Mt of CO_2 - ref approach)	**4172,0**	**3950,7**	**3922,7**	**4087,6**	**3835,6**	**3637,6**	**3325,0**	**3227,5**	**2957,6**	**2741,6**	**2568,2**	**2459,9**	**2402,7**	**-0,6**	**-0,2**	**-1,4**	**-1,2**	**-1,4**	**-0,7**

EU27: Reference scenario with high world energy prices — SUMMARY ENERGY BALANCE AND INDICATORS (B)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12750,3	14164,0	15503,7	16824,7	18157,1	19527,9	21002,9	22560,0	2,2	1,2	2,2	1,7	1,5	1,5
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	155,9	138,3	122,6	110,9	100,3	93,3	87,7	82,5	76,6	-1,8	-0,9	-2,4	-2,0	-1,3	-1,3
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,55	3,47	3,38	3,32	3,25	3,25	3,29	3,34	3,35	0,1	-0,1	-0,5	-0,4	0,1	0,2
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6824	7188	7453	7768	7892	8288	8752	9222	9611	1,3	0,9	0,9	0,6	1,0	0,9
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,12	2,03	1,88	1,84	1,71	1,58	1,46	1,38	1,35	-0,9	-0,4	-1,2	-0,9	-1,6	-0,8
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,55	7,04	6,34	6,11	5,56	5,14	4,81	4,63	4,53	-0,8	-0,5	-1,7	-1,3	-1,4	-0,6
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	331,1	280,2	230,0	204,0	171,7	147,3	128,2	114,1	103,5	-2,7	-1,3	-3,6	-2,9	-2,9	-2,1
Import Dependency %	44,6	43,5	46,8	52,5	53,7	54,9	54,6	54,7	53,7	53,2	53,1	53,6	54,7						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	90,2	83,3	76,4	70,6	65,9	62,6	60,3	58,2	56,3	-2,6	-1,0	-1,6	-1,5	-0,9	-0,7
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,9	86,5	76,4	67,1	61,4	56,1	52,0	48,0	44,5	-1,3	-0,3	-2,3	-2,2	-1,6	-1,6
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	94,7	84,0	73,3	65,5	59,0	55,5	52,1	49,0	45,4	-2,3	-0,5	-2,5	-2,2	-1,2	-1,4
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	86,8	79,9	73,2	66,2	62,1	57,8	53,8	50,0	-0,2	-0,3	-1,9	-1,9	-1,3	-1,4
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,32	0,28	0,23	0,22	0,18	0,14	0,11	0,09	0,08	-2,1	-1,5	-3,2	-2,5	-5,2	-3,1
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,93	1,80	1,69	1,65	1,60	1,57	1,54	1,52	1,50	-0,7	-0,8	-1,3	-0,6	-0,4	-0,3
Industry	2,14	2,06	1,91	1,78	1,57	1,41	1,30	1,22	1,18	1,13	1,10	1,12	1,11	-1,1	-1,9	-1,9	-1,0	-0,6	0,1
Residential	1,89	1,72	1,63	1,58	1,51	1,38	1,23	1,15	1,10	1,08	1,04	1,00	0,95	-1,5	-0,7	-2,0	-1,1	-0,6	-0,9
Tertiary	1,90	1,72	1,51	1,48	1,40	1,24	1,12	1,06	0,99	0,95	0,89	0,84	0,80	-2,2	-0,8	-2,2	-1,2	-1,1	-1,0
Transport	2,90	2,90	2,91	2,91	2,83	2,74	2,65	2,65	2,60	2,60	2,59	2,59	2,59	0,0	-0,3	-0,7	-0,2	0,0	0,0
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654125**	**715732**	**820434**	**932620**	**1032788**	**1088775**	**1185453**	**1265492**	**1349640**	**1430349**	**1506216**		**2,3**	**2,3**	**1,4**	**1,3**	**1,1**
Nuclear energy			133923	134409	127038	126852	125074	121722	133458	144906	150509	161560	167287		-0,5	-0,2	0,7	1,2	1,1
Renewable energy			112878	147262	209099	284114	408330	464725	554444	604967	649863	690341	731802		6,4	6,9	3,1	1,6	1,2
Hydro (pumping excluded)			99714	104505	107315	110895	114221	115796	117764	119063	119318	120171	121417		0,7	0,6	0,3	0,1	0,2
Wind			12793	40584	86229	144788	234861	274238	333105	360201	378940	390489	405677		21,0	10,5	3,6	1,3	0,7
Solar			371	2172	15307	27855	57573	71822	99427	121232	146775	174191	198094		45,1	14,2	5,6	4,0	3,0
Other renewables (tidal etc.)			0	1	249	575	1675	2869	4149	4471	4831	5490	6613			21,0	9,5	1,5	3,2
Thermal power			407324	434061	484297	521655	499384	502328	497550	515619	549267	578448	607127		1,7	0,3	0,0	1,0	1,0
of which cogeneration units			75904	85934	100075	116174	120571	129350	132766	154717	170230	189330	199103		2,8	1,9	1,0	2,5	1,6
of which CCS units			0	0	0	0	5394	5394	5993	20336	44660	66821	80397				1,1	22,2	6,1
Solids fired			194165	186620	183838	184942	168479	153118	135450	130306	138607	143502	141235		-0,5	-0,9	-2,2	0,2	0,2
Gas fired			129444	167173	219347	240391	230027	229494	240992	264602	258102	234589	200906		5,4	0,5	0,5	0,7	-2,5
Oil fired			71058	62082	56158	51358	41013	51543	49191	47697	74720	115244	174538		-2,3	-3,1	1,8	4,3	8,9
Biomass-waste fired			12051	17502	24171	44170	59038	67290	70972	72031	76814	84081	89408		7,2	9,3	1,9	0,8	1,5
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	684	783	794	826	884	945	982	1024	1032	1039		2,6	0,5	1,4	0,8	0,1
Load factor for net electric capacities (%)			49,1	49,1	45,1	42,6	40,3	40,2	37,8	37,1	36,4	35,9	35,3						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,2	39,7	40,0	40,0	39,3	41,1	42,6	43,6	44,3						
CHP indicator (% of electricity from CHP)			11,4	11,7	15,0	18,2	18,2	18,4	18,0	20,9	21,4	22,0	22,6						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	1,3	1,3	1,5	4,7	9,4	12,9	14,4						
Non fossil fuels in electricity generation (%)			45,8	44,8	46,0	49,9	56,8	59,5	66,0	68,4	68,7	69,2	69,6						
- nuclear			31,6	30,5	27,2	25,5	23,7	23,8	25,4	26,9	26,9	27,6	27,4						
- renewable energy forms and industrial waste			14,2	14,3	18,8	24,4	33,0	35,7	40,6	41,5	41,9	41,6	42,1						
Indicators for renewables (excluding industrial waste) (%) [B]																			
RES in gross final energy demand (%)			7,6	8,6	11,4	15,9	22,0	23,1	25,5	26,0	26,6	26,7	27,2						
RES in transport (%)			0,5	1,4	4,3	8,1	12,1	12,0	14,1	14,3	14,5	14,6	14,7						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**6920,7**	**7346,1**	**7813,6**	**8179,2**	**8562,5**	**8856,9**	**9095,3**	**9278,9**	**1,9**	**1,0**	**1,2**	**1,1**	**0,8**	**0,5**
Public road transport	544,0	504,0	517,6	526,0	545,0	564,3	590,4	613,3	630,9	646,7	659,3	669,0	675,9	-0,5	0,5	0,8	0,7	0,4	0,2
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,1	5127,6	5371,6	5654,0	5853,2	6098,3	6261,0	6379,0	6453,3	2,4	0,9	1,0	0,9	0,7	0,3
Rail	472,5	421,7	447,9	461,0	482,5	522,2	562,7	603,3	640,2	676,6	712,3	742,7	765,3	-0,5	0,7	1,5	1,3	1,1	0,7
Aviation	317,3	351,3	456,9	527,3	576,9	665,1	778,5	898,8	1009,6	1094,4	1177,0	1256,4	1335,6	3,7	2,4	3,0	2,6	1,5	1,3
Inland navigation	45,8	44,4	41,7	39,5	40,8	41,5	42,9	44,2	45,4	46,5	47,4	48,1	48,7	-0,9	-0,2	0,5	0,6	0,4	0,3
Travel per person (km per capita)	10376	11127	12248	12756	13039	13631	14297	15090	15731	16446	17029	17546	18007	1,7	0,6	0,9	1,0	0,8	0,6
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2874,8**	**3043,7**	**3229,8**	**3361,7**	**3513,1**	**3635,9**	**3733,1**	**3806,0**	**1,7**	**1,9**	**1,3**	**1,0**	**0,8**	**0,5**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2094,4	2210,3	2351,1	2447,7	2566,2	2659,9	2734,4	2789,9	3,7	2,5	1,3	1,0	0,8	0,5
Rail	526,3	386,1	403,7	414,1	440,5	486,4	523,0	552,9	576,5	598,6	619,3	636,1	650,2	-2,6	0,9	1,7	1,0	0,7	0,5
Inland navigation	261,6	267,6	273,3	280,2	281,9	294,0	310,4	325,8	337,5	348,3	356,6	362,6	365,9	0,4	0,3	1,0	0,8	0,6	0,3
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	225	215	208	200	193	186	178	169	-0,4	0,7	-0,8	-0,7	-0,7	-1,0
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**370013**	**371769**	**379996**	**381024**	**373824**	**378321**	**379157**	**379661**	**378542**	**1,9**	**0,9**	**0,3**	**-0,2**	**0,1**	**0,0**
Public road transport	5197	4732	4914	5039	5182	5241	5217	5127	4996	5000	4954	4800	4611	-0,6	0,5	0,1	-0,4	-0,1	-0,7
Private cars and motorcycles	154395	166321	182974	187736	186451	179691	178111	177039	170966	168974	166164	163291	161068	1,7	0,2	-0,5	-0,4	-0,3	-0,3
Trucks	74969	79037	90951	105104	111606	119627	122608	125516	124745	128357	131002	132630	133993	2,0	2,1	0,9	0,2	0,5	0,2
Rail	9560	9452	9600	9436	9599	9909	9705	9480	8429	8381	8507	8559	8534	0,0	0,0	0,1	-1,4	0,1	0,0
Aviation	29038	34112	45395	49703	51709	51732	58532	57778	58429	61191	61993	63776	63710	4,6	1,3	1,2	0,0	0,6	0,3
Inland navigation	7110	6963	5555	5386	5466	5570	5823	6084	6258	6417	6537	6606	6626	-2,4	-0,2	0,6	0,7	0,4	0,1
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	34,8	33,5	31,2	29,2	28,0	26,8	26,0	25,2	0,2	-0,6	-1,3	-1,4	-0,8	-0,6
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,1	45,6	44,1	42,4	40,2	39,5	39,0	38,4	38,1	-0,2	-0,1	-0,4	-0,9	-0,3	-0,2

Reference scenario with High GDP

EU27: Reference High Economic Growth scenario														SUMMARY ENERGY BALANCE AND INDICATORS (A)					
ktoe	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**'90-'00**	**'00-'10**	**'10-'20**	**'20-'30**	**'30-'40**	**'40-'50**
														Annual % Change					
Production	**936047**	**950181**	**941860**	**900326**	**844795**	**805982**	**796733**	**793722**	**804699**	**829870**	**845820**	**851510**	**837989**	**0,1**	**-1,1**	**-0,6**	**0,1**	**0,5**	**-0,1**
Solids	366477	277810	213423	196277	182261	166301	146303	139267	120159	117873	123351	127247	125408	-5,3	-1,6	-2,2	-1,9	0,3	0,2
Oil	129551	171052	173006	134290	104398	74368	49705	41001	37493	32839	26195	17846	8973	2,9	-4,9	-7,2	-2,8	-3,5	-10,2
Natural gas	162447	188965	207559	188677	164866	129073	110925	90885	74874	64386	52719	39166	29766	2,5	-2,3	-3,9	-3,9	-3,4	-5,6
Nuclear	202589	223028	243761	257360	238966	240206	228713	240108	263627	296309	317134	332743	333617	1,9	-0,2	-0,4	1,4	1,9	0,5
Renewable energy sources	74984	89326	104111	123722	154305	196035	261087	282462	308546	318464	326422	334508	340226	3,3	4,0	5,4	1,7	0,6	0,4
Hydro	25101	28054	30374	26395	27808	28644	29330	30146	30666	31053	31422	31760	32027	1,9	-0,9	0,5	0,4	0,2	0,2
Biomass & Waste	46473	57201	67982	85129	102388	122697	154221	162033	167512	165469	165881	167713	165312	3,9	4,2	4,2	0,8	-0,1	0,0
Wind	67	350	1913	6061	13850	27893	48425	58176	72406	79767	83465	86748	91095	39,8	21,9	13,3	4,1	1,4	0,9
Solar and others	153	274	421	807	3426	9356	20069	22772	28368	32197	35350	37880	41257	10,7	23,3	19,3	3,5	2,2	1,6
Geothermal	3190	3447	3421	5331	6833	7444	9041	9335	9594	9979	10304	10407	10535	0,7	7,2	2,8	0,6	0,7	0,2
Net Imports	**756079**	**738600**	**826299**	**986048**	**980018**	**1057089**	**1074775**	**1073938**	**1041883**	**1047990**	**1073402**	**1108378**	**1139953**	**0,9**	**1,7**	**0,9**	**-0,3**	**0,3**	**0,6**
Solids	81846	79338	98645	126639	121884	122639	115056	123838	94444	86849	95985	98324	104049	1,9	2,1	-0,6	-2,0	0,2	0,8
Oil	535645	512185	533039	599851	581718	611820	627907	623035	606259	613906	623192	638522	653294	0,0	0,9	0,8	-0,4	0,3	0,5
- Crude oil and Feedstocks	508460	494000	513725	581995	579041	613293	633140	632742	619281	627290	636576	651754	666926	0,1	1,2	0,9	-0,2	0,3	0,5
- Oil products	27185	18185	19314	17856	2678	-1473	-5233	-9706	-13021	-13384	-13384	-13233	-13633	-3,4	-17,9				
Natural gas	135121	145288	192531	257366	272319	315863	313499	313865	326151	330246	334777	348769	356333	3,6	3,5	1,4	0,4	0,3	0,6
Electricity	3323	1508	1686	971	264	-544	-1754	-1942	-2080	-2327	-2342	-2395	-2487	-6,6	-16,9				
Renewable energy forms	144	279	397	1222	3834	7311	20067	15142	17109	19317	21790	25158	28765	10,7	25,4	18,0	-1,6	2,4	2,8
Gross Inland Consumption	**1660159**	**1662517**	**1723099**	**1825989**	**1774762**	**1811013**	**1817263**	**1811162**	**1787554**	**1816497**	**1855568**	**1894099**	**1910524**	**0,4**	**0,3**	**0,2**	**-0,2**	**0,4**	**0,3**
Solids	452940	364248	321007	319922	304145	288940	261360	263105	214603	204722	219336	225571	229456	-3,4	-0,5	-1,5	-2,0	0,2	0,5
Oil	631058	650858	658727	676859	636065	634131	623367	607538	584725	585381	585733	590579	594848	0,4	-0,3	-0,2	-0,6	0,0	0,2
Natural gas	294905	333268	393417	445998	437184	444936	424424	404750	401026	394632	387496	387935	386099	2,9	1,1	-0,3	-0,6	-0,3	0,0
Nuclear	202589	223028	243761	257360	238966	240206	228713	240108	263627	296309	317134	332743	333617	1,9	-0,2	-0,4	1,4	1,9	0,5
Electricity	3323	1508	1686	971	264	-544	-1754	-1942	-2080	-2327	-2342	-2395	-2487	-6,6	-16,9				
Renewable energy forms	75343	89606	104501	124880	158139	203345	281154	297604	325654	337781	348212	359665	368991	3,3	4,2	5,9	1,5	0,7	0,6
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	17,1	16,0	14,4	14,5	12,0	11,3	11,8	11,9	12,0						
Oil	38,0	39,1	38,2	37,1	35,8	35,0	34,3	33,5	32,7	32,2	31,6	31,2	31,1						
Natural gas	17,8	20,0	22,8	24,4	24,6	24,6	23,4	22,3	22,4	21,7	20,9	20,5	20,2						
Nuclear	12,2	13,4	14,1	14,1	13,5	13,3	12,6	13,3	14,7	16,3	17,1	17,6	17,5						
Renewable energy forms	4,5	5,4	6,1	6,8	8,9	11,2	15,5	16,4	18,2	18,6	18,8	19,0	19,3						
Gross Electricity Generation in GWh_e	**2562823**	**2712209**	**2991720**	**3274121**	**3409095**	**3621318**	**3828968**	**4091878**	**4228912**	**4537561**	**4857644**	**5154945**	**5386239**	**1,6**	**1,3**	**1,2**	**1,0**	**1,4**	**1,0**
Nuclear	794718	881662	944823	997519	926731	932507	893541	953446	1060642	1206092	1298803	1400788	1475992	1,7	-0,2	-0,4	1,7	2,0	1,3
Hydro & wind	292648	330306	375545	378836	501839	690568	975998	1120891	1341556	1465426	1545707	1615257	1705595	2,5	2,9	6,9	3,2	1,4	1,0
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1980524	1998244	1959429	2017541	1826713	1866043	2013134	2138899	2204651	1,3	1,7	-0,1	-0,7	1,0	0,9
Fuel Inputs for Thermal Power Generation	**383492**	**362334**	**382613**	**424208**	**434107**	**430405**	**418618**	**427545**	**388791**	**383108**	**399468**	**411556**	**418690**	**0,0**	**1,3**	**-0,4**	**-0,7**	**0,3**	**0,5**
Solids	263837	230040	223012	229245	232504	218931	194258	198294	154921	146530	159714	163990	167715	-1,7	0,4	-1,8	-2,2	0,3	0,5
Oil (including refinery gas)	54404	51463	39294	29780	17334	16556	11415	14021	14737	17472	20189	23532	24049	-3,2	-7,9	-4,1	2,6	3,2	1,8
Gas	56754	67806	102408	134637	143332	139894	131289	125399	124477	124863	123931	126928	127935	6,1	3,4	-0,9	-0,5	0,0	0,3
Biomass & Waste	5724	10033	14960	25901	35109	49098	75487	83207	87570	86876	87928	89343	91171	10,1	8,9	8,0	1,5	0,0	0,4
Geothermal heat	2774	2992	2939	4645	5828	5925	6169	6624	7086	7366	7706	7763	7819	0,6	7,1	0,6	1,4	0,8	0,1
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0	0	0	0	0						
Fuel Input in other transformation proc.	**839073**	**814654**	**827098**	**842975**	**794418**	**806148**	**810199**	**799928**	**779857**	**783664**	**787709**	**795474**	**800639**	**-0,1**	**-0,4**	**0,2**	**-0,4**	**0,1**	**0,2**
Refineries	679426	705954	735244	758152	718881	723084	717498	707606	689558	692938	695366	702005	708441	0,8	-0,2	0,0	-0,4	0,1	0,2
Biofuels and hydrogen production	2	202	610	3129	12210	19684	30839	32756	36418	38224	39050	39460	39487	79,6	34,9	9,7	1,7	0,7	0,1
District heating	32960	23240	19323	16212	15817	16087	16095	15726	14180	13407	12900	12828	12598	-5,2	-2,0	0,2	-1,3	-0,9	-0,2
Others	126685	85258	71921	65482	47510	47293	45766	43839	39701	39095	40393	41180	40113	-5,5	-4,1	-0,4	-1,4	0,2	-0,1
Energy Branch Consumption	**82379**	**88696**	**88176**	**96033**	**92198**	**90788**	**90471**	**89968**	**85921**	**88889**	**93395**	**96777**	**98155**	**0,7**	**0,4**	**-0,2**	**-0,5**	**0,8**	**0,5**
Non-Energy Uses	**97931**	**110541**	**112495**	**117477**	**111500**	**115433**	**119102**	**121307**	**123892**	**126644**	**129190**	**131854**	**134077**	**1,4**	**-0,1**	**0,7**	**0,4**	**0,4**	**0,4**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173676**	**1165859**	**1218531**	**1246318**	**1234451**	**1225255**	**1245750**	**1266720**	**1294011**	**1310550**	**0,4**	**0,5**	**0,7**	**-0,2**	**0,3**	**0,3**
by sector																			
Industry	365650	328513	326949	326308	312372	322924	333322	339324	344326	356127	372071	389175	405600	-1,1	-0,5	0,7	0,3	0,8	0,9
- energy intensive industries	234722	214526	213112	210991	193231	196619	199939	199567	199113	201995	207814	212529	216414	-1,0	-1,0	0,3	0,0	0,4	0,4
- other industrial sectors	130928	113987	113837	115317	119142	126305	133383	139757	145213	154132	164258	176646	189186	-1,4	0,5	1,1	0,9	1,2	1,4
Residential	264307	280418	286784	308104	308383	322112	323297	309148	304520	302824	298664	298297	293592	0,8	0,7	0,5	-0,6	-0,2	-0,2
Tertiary	158484	160442	159866	176859	175093	183577	185456	184433	184752	190957	197191	203880	207732	0,1	0,9	0,6	0,0	0,7	0,5
Transport	280269	300617	339389	362405	370011	389918	404242	401547	391657	395841	398794	402658	403627	1,9	0,9	0,9	-0,3	0,2	0,1
by fuel																			
Solids	125031	84977	61454	54486	47491	46096	44227	42397	38492	37764	38962	41320	41896	-6,9	-2,5	-0,7	-1,4	0,1	0,7
Oil	444429	456959	478882	495857	476571	478214	474500	460227	440224	441351	442253	446490	446418	0,7	0,0	0,0	-0,7	0,0	0,1
Gas	227902	245996	265552	283524	264953	273631	258825	242087	237168	228479	221069	217048	213656	1,5	0,0	-0,2	-0,9	-0,7	-0,3
Electricity	184145	193367	216403	237537	248326	265073	279453	298023	309264	329949	350504	370481	386639	1,6	1,4	1,2	1,0	1,3	1,0
Heat (from CHP and District Heating) (A)	48610	44616	40061	44441	59517	71959	79203	85228	88610	95932	100990	104078	106474	-1,9	4,0	2,9	1,1	1,3	0,5
Other	38592	44073	50640	57832	69001	83557	110108	106489	111496	112276	112941	114593	115468	2,8	3,1	4,8	0,1	0,1	0,2
CO_2 Emissions (Mt of CO_2 - sec approach)	**4030,6**	**3800,1**	**3810,6**	**3946,6**	**3771,8**	**3714,7**	**3482,3**	**3342,8**	**3018,1**	**2804,4**	**2649,7**	**2560,6**	**2527,9**	**-0,6**	**-0,1**	**-0,8**	**-1,4**	**-1,3**	**-0,5**
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1365,6	1300,3	1130,7	1090,9	864,2	682,0	546,0	453,8	426,2	-1,2	0,3	-1,9	-2,7	-4,5	-2,4
Energy Branch	152,2	171,0	170,2	181,6	157,2	146,3	136,7	127,2	117,6	105,5	95,1	83,7	83,5	1,1	-0,8	-1,4	-1,5	-2,1	-1,3
Industry	781,4	678,1	623,0	581,9	490,8	474,8	462,5	448,2	433,7	428,4	439,7	458,0	475,7	-2,2	-2,4	-0,6	-0,6	0,1	0,8
Residential	499,4	481,6	466,2	486,7	465,3	468,7	434,1	389,3	368,3	353,7	333,9	322,6	303,4	-0,7	0,0	-0,7	-1,6	-1,0	-1,0
Tertiary	300,5	275,3	242,0	262,2	244,5	239,4	224,7	208,4	198,7	192,8	187,0	184,6	178,2	-2,1	0,1	-0,8	-1,2	-0,6	-0,5
Transport	812,7	872,9	988,5	1053,1	1048,3	1085,2	1093,5	1078,8	1035,7	1042,0	1048,0	1058,0	1060,8	2,0	0,6	0,4	-0,5	0,1	0,1
CO_2 Emissions Index (1990=100)	**100,0**	**94,3**	**94,5**	**97,9**	**93,6**	**92,2**	**86,4**	**82,9**	**74,9**	**69,6**	**65,7**	**63,5**	**62,7**						
CO_2 Emissions (Mt of CO_2 - ref approach)	**4172,0**	**3950,7**	**3922,7**	**4087,6**	**3837,8**	**3781,1**	**3552,7**	**3412,0**	**3090,1**	**2875,5**	**2719,7**	**2629,1**	**2600,6**	**-0,6**	**-0,2**	**-0,8**	**-1,4**	**-1,3**	**-0,4**

EU27: Reference High Economic Growth scenario														SUMMARY ENERGY BALANCE AND INDICATORS (B)					
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12801,7	14487,7	16165,8	17888,9	19687,4	21595,7	23690,1	25953,1	2,2	1,2	2,4	2,1	1,9	1,9
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	155,9	141,5	125,4	112,0	99,9	92,3	85,9	80,0	73,6	-1,8	-0,9	-2,1	-2,2	-1,5	-1,5
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,55	3,57	3,54	3,50	3,44	3,49	3,57	3,65	3,71	0,1	-0,1	0,0	-0,3	0,4	0,4
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6827	7132	7452	7902	8133	8715	9340	9945	10453	1,3	0,9	0,9	0,9	1,4	1,1
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,13	2,05	1,92	1,85	1,69	1,54	1,43	1,35	1,32	-0,9	-0,4	-1,0	-1,3	-1,7	-0,8
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,55	7,32	6,78	6,46	5,80	5,39	5,09	4,94	4,91	-0,8	-0,5	-1,1	-1,5	-1,3	-0,4
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	331,3	290,2	240,4	206,8	168,7	142,4	122,7	108,1	97,4	-2,7	-1,3	-3,2	-3,5	-3,1	-2,3
Import Dependency %	44,6	43,5	46,8	52,5	53,7	56,7	57,4	57,5	56,4	55,8	55,9	56,6	57,6						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	90,3	84,2	77,7	71,7	66,7	63,1	60,7	58,4	56,2	-2,6	-1,0	-1,5	-1,5	-0,9	-0,8
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,9	89,6	80,2	70,9	64,8	58,8	54,3	50,0	46,2	-1,3	-0,3	-1,9	-2,1	-1,8	-1,6
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	94,7	87,5	77,6	68,7	61,9	57,9	54,2	50,9	47,0	-2,3	-0,5	-2,0	-2,2	-1,3	-1,4
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	90,7	83,1	74,0	65,2	59,9	55,0	50,6	46,3	-0,2	-0,3	-1,5	-2,4	-1,7	-1,7
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,32	0,28	0,23	0,21	0,16	0,12	0,09	0,07	0,06	-2,1	-1,5	-3,3	-3,6	-5,8	-3,3
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,93	1,86	1,78	1,72	1,66	1,62	1,59	1,56	1,54	-0,7	-0,8	-0,8	-0,7	-0,5	-0,3
Industry	2,14	2,06	1,91	1,78	1,57	1,47	1,39	1,32	1,26	1,20	1,18	1,18	1,17	-1,1	-1,9	-1,2	-1,0	-0,6	-0,1
Residential	1,89	1,72	1,63	1,58	1,51	1,46	1,34	1,26	1,21	1,17	1,12	1,08	1,03	-1,5	-0,7	-1,2	-1,0	-0,8	-0,8
Tertiary	1,90	1,72	1,51	1,48	1,40	1,30	1,21	1,13	1,08	1,01	0,95	0,91	0,86	-2,2	-0,8	-1,4	-1,2	-1,2	-1,0
Transport	2,90	2,90	2,91	2,91	2,83	2,78	2,71	2,69	2,64	2,63	2,63	2,63	2,63	0,0	-0,3	-0,5	-0,2	-0,1	0,0
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654125**	**715732**	**820290**	**923627**	**1029084**	**1089097**	**1196428**	**1294316**	**1386766**	**1481291**	**1570140**		**2,3**	**2,3**	**1,5**	**1,5**	**1,2**
Nuclear energy			133923	134409	127038	126752	124722	120598	134152	149442	159029	171948	182410		-0,5	-0,2	0,7	1,7	1,4
Renewable energy			112878	147262	209088	282215	405981	462606	554904	605631	641787	674521	717321		6,4	6,9	3,2	1,5	1,1
Hydro (pumping excluded)			99714	104505	107315	110860	114167	115744	117580	119033	119293	120198	121500		0,7	0,6	0,3	0,1	0,2
Wind			12793	40584	86217	142925	233040	272784	331498	359395	374199	387366	404075		21,0	10,5	3,6	1,2	0,8
Solar			371	2172	15307	27855	57104	71209	101678	122732	143464	161404	185077		45,1	14,1	5,9	3,5	2,6
Other renewables (tidal etc.)			0	1	249	575	1671	2869	4148	4471	4831	5552	6669			21,0	9,5	1,5	3,3
Thermal power			407324	434061	484164	514659	498381	505893	507371	539243	585950	634823	670409		1,7	0,3	0,2	1,5	1,4
of which cogeneration units			75904	85934	100381	114328	119605	131172	137134	161453	186324	210378	227948		2,8	1,8	1,4	3,1	2,0
of which CCS units			0	0	0	0	5394	11086	17169	40385	77112	110122	126199				12,3	16,2	5,0
Solids fired			194165	186620	183827	183101	166344	152693	141300	140709	150515	149707	147538		-0,5	-1,0	-1,6	0,6	-0,2
Gas fired			129444	167173	219320	239092	231438	230128	239996	270827	283217	275309	239631		5,4	0,5	0,4	1,7	-1,7
Oil fired			71058	62082	56063	49370	39978	53722	52024	51793	71234	122299	192448		-2,3	-3,3	2,7	3,2	10,4
Biomass-waste fired			12051	17502	24170	42305	59797	68467	73107	74933	79957	86474	89751		7,2	9,5	2,0	0,9	1,2
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	684	783	791	823	884	945	982	1027	1035	1042		2,6	0,5	1,4	0,8	0,1
Load factor for net electric capacities (%)			49,1	49,1	45,1	42,7	40,5	40,8	38,4	37,9	37,5	37,1	36,5						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,2	39,9	40,3	40,6	40,4	41,9	43,3	44,7	45,3						
CHP indicator (% of electricity from CHP)			11,4	11,7	15,0	18,0	18,5	18,6	18,3	20,8	22,1	23,0	23,2						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	1,4	2,8	4,2	8,8	14,9	19,2	20,3						
Non fossil fuels in electricity generation (%)			45,8	44,8	45,9	50,1	56,4	58,6	64,9	66,5	65,9	65,7	66,2						
- nuclear			31,6	30,5	27,2	25,8	23,3	23,3	25,1	26,6	26,7	27,2	27,4						
- renewable energy forms and industrial waste			14,2	14,3	18,7	24,3	33,0	35,3	39,8	39,9	39,2	38,5	38,8						
Indicators for renewables (excluding industrial waste) (%) [B]																			
RES in gross final energy demand (%)			7,6	8,6	11,4	14,6	20,1	21,4	23,7	24,1	24,3	24,4	24,9						
RES in transport (%)			0,5	1,4	4,3	6,6	10,1	10,9	12,5	13,1	13,2	13,3	13,2						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**7186,5**	**7787,5**	**8227,1**	**8648,1**	**9035,3**	**9300,3**	**9581,3**	**9754,9**	**1,9**	**1,0**	**1,8**	**1,1**	**0,7**	**0,5**
Public road transport	544,0	504,0	517,6	526,0	545,0	576,1	613,5	636,3	655,6	673,9	684,6	696,5	702,5	-0,5	0,5	1,2	0,7	0,4	0,3
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,1	5341,1	5715,6	5965,4	6208,3	6441,8	6577,7	6726,0	6788,8	2,4	0,9	1,6	0,8	0,6	0,3
Rail	472,5	421,7	447,9	461,0	482,5	528,0	576,4	616,5	654,6	694,6	727,7	760,6	782,9	-0,5	0,7	1,8	1,3	1,1	0,7
Aviation	317,3	351,3	456,9	527,3	576,9	699,0	837,4	962,9	1082,5	1176,4	1260,9	1348,0	1429,9	3,7	2,4	3,8	2,6	1,5	1,3
Inland navigation	45,8	44,4	41,7	39,5	40,8	42,3	44,6	46,0	47,2	48,6	49,4	50,3	50,8	-0,9	-0,2	0,9	0,6	0,4	0,3
Travel per person (km per capita)	10376	11127	12248	12756	13039	14154	15155	15888	16633	17354	17882	18484	18930	1,7	0,6	1,5	0,9	0,7	0,6
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2980,3**	**3234,9**	**3473,5**	**3699,4**	**3915,2**	**4127,1**	**4325,5**	**4496,8**	**1,7**	**1,9**	**2,0**	**1,4**	**1,1**	**0,9**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2188,4	2372,4	2548,2	2717,3	2878,5	3037,6	3188,6	3317,0	3,7	2,5	2,0	1,4	1,1	0,9
Rail	526,3	386,1	403,7	414,1	440,5	492,3	539,8	580,3	617,4	653,5	689,4	722,0	752,7	-2,6	0,9	2,1	1,4	1,1	0,9
Inland navigation	261,6	267,6	273,3	280,2	281,9	299,5	322,8	345,1	364,7	383,2	400,1	414,9	427,1	0,4	0,3	1,4	1,2	0,9	0,7
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	233	223	215	207	199	191	183	173	-0,4	0,7	-0,5	-0,8	-0,8	-1,0
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**370011**	**389918**	**404242**	**401547**	**391657**	**395841**	**398794**	**402658**	**403627**	**1,9**	**0,9**	**0,9**	**-0,3**	**0,2**	**0,1**
Public road transport	5197	4732	4914	5039	5182	5334	5391	5284	5145	5147	5092	4956	4753	-0,6	0,5	0,4	-0,5	-0,1	-0,7
Private cars and motorcycles	154395	166321	182974	187736	186451	186412	186566	177813	167337	164525	161244	158521	155378	1,7	0,2	0,0	-1,1	-0,4	-0,4
Trucks	74969	79037	90951	105104	111606	124207	130639	135054	136977	142062	147194	151609	155668	2,0	2,1	1,6	0,5	0,7	0,6
Rail	9560	9452	9600	9436	9597	10196	10221	9997	8889	8890	9101	9246	9314	0,0	0,0	0,6	-1,4	0,2	0,2
Aviation	29038	34112	45395	49703	51709	58128	65393	67031	66684	68344	69089	71088	71173	4,6	1,3	2,4	0,2	0,4	0,3
Inland navigation	7110	6963	5555	5386	5466	5642	6033	6368	6625	6873	7074	7239	7341	-2,4	-0,2	1,0	0,9	0,7	0,4
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	35,3	33,6	30,9	28,2	26,8	25,8	24,9	24,2	0,2	-0,6	-1,2	-1,7	-0,9	-0,7
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,1	45,6	44,1	42,4	40,0	39,2	38,5	37,8	37,3	-0,2	-0,1	-0,4	-1,0	-0,4	-0,3

Reference scenario with Low GDP

EU27: Reference Low Economic Growth scenario														SUMMARY ENERGY BALANCE AND INDICATORS (A)					
ktoe	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**'90-'00**	**'00-'10**	**'10-'20**	**'20-'30**	**'30-'40**	**'40-'50**
														Annual % Change					
Production	**936047**	**950181**	**941860**	**900326**	**844967**	**798425**	**774117**	**758145**	**735176**	**728353**	**728490**	**723698**	**704387**	**0,1**	**-1,1**	**-0,9**	**-0,5**	**-0,1**	**-0,3**
Solids	366477	277810	213423	196277	182279	164758	144498	136490	112424	100470	104565	104099	105717	-5,3	-1,6	-2,3	-2,5	-0,7	0,1
Oil	129551	171052	173006	134290	104398	72977	48126	39228	35670	30897	24132	16128	7824	2,9	-4,9	-7,5	-3,0	-3,8	-10,7
Natural gas	162447	188965	207559	188677	164866	129027	110780	90584	74147	62848	50575	36387	28338	2,5	-2,3	-3,9	-3,9	-3,8	-5,6
Nuclear	202589	223028	243761	257360	238973	238589	215041	219504	223045	237771	244630	260234	255129	1,9	-0,2	-1,0	0,4	0,9	0,4
Renewable energy sources	74984	89326	104111	123722	154452	193073	255672	272340	289890	296367	304588	306849	307379	3,3	4,0	5,2	1,3	0,5	0,1
Hydro	25101	28054	30374	26395	27808	28606	29328	30119	30642	31003	31403	31730	31998	1,9	-0,9	0,5	0,4	0,2	0,2
Biomass & Waste	46473	57201	67982	85129	102535	120731	150880	155817	156950	154394	156770	154579	151269	3,9	4,2	3,9	0,4	0,0	-0,4
Wind	67	350	1913	6061	13850	27166	47475	55790	67085	72196	75277	77925	78988	39,8	21,9	13,1	3,5	1,2	0,5
Solar and others	153	274	421	807	3427	9199	19127	21531	25900	29156	31241	32666	35097	10,7	23,3	18,8	3,1	1,9	1,2
Geothermal	3190	3447	3421	5331	6832	7372	8861	9083	9313	9619	9897	9949	10027	0,7	7,2	2,6	0,5	0,6	0,1
Net Imports	**756079**	**738600**	**826299**	**986048**	**979925**	**1028626**	**1011130**	**991603**	**959207**	**944014**	**938476**	**941536**	**944714**	**0,9**	**1,7**	**0,3**	**-0,5**	**-0,2**	**0,1**
Solids	81846	79338	98645	126639	121926	117364	103990	110841	97361	81198	69066	65468	62407	1,9	2,1	-1,6	-0,7	-3,4	-1,0
Oil	535645	512185	533039	599851	581615	598342	600353	585221	559786	554950	555216	558460	562003	0,0	0,9	0,3	-0,7	-0,1	0,1
- Crude oil and Feedstocks	508460	494000	513725	581995	578948	602707	609655	600707	580305	577397	579027	583528	588713	0,1	1,2	0,5	-0,5	0,0	0,2
- Oil products	27185	18185	19314	17856	2667	-4365	-9302	-15486	-20519	-22447	-23812	-25068	-26711	-3,4	-18,0				
Natural gas	135121	145288	192531	257366	272266	306353	289972	282741	287800	291897	295531	296951	296064	3,6	3,5	0,6	-0,1	0,3	0,0
Electricity	3323	1508	1686	971	264	-544	-1754	-1942	-2080	-2327	-2342	-2395	-2487	-6,6	-16,9				
Renewable energy forms	144	279	397	1222	3855	7112	18569	14741	16341	18296	21005	23052	26728	10,7	25,5	17,0	-1,3	2,5	2,4
Gross Inland Consumption	**1660159**	**1662517**	**1723099**	**1825989**	**1774841**	**1776206**	**1734308**	**1698742**	**1643155**	**1621172**	**1615915**	**1614511**	**1599130**	**0,4**	**0,3**	**-0,2**	**-0,5**	**-0,2**	**-0,1**
Solids	452940	364248	321007	319922	304204	282122	248488	247331	209785	181668	173631	169567	168124	-3,4	-0,5	-2,0	-1,7	-1,9	-0,3
Oil	631058	650858	658727	676859	635961	620474	597540	573443	544227	534653	528296	523865	519855	0,4	-0,4	-0,6	-0,9	-0,3	-0,2
Natural gas	294905	333268	393417	445998	437131	435380	400752	373325	361947	354745	346106	333338	324402	2,9	1,1	-0,9	-1,0	-0,4	-0,6
Nuclear	202589	223028	243761	257360	238973	238589	215041	219504	223045	237771	244630	260234	255129	1,9	-0,2	-1,0	0,4	0,9	0,4
Electricity	3323	1508	1686	971	264	-544	-1754	-1942	-2080	-2327	-2342	-2395	-2487	-6,6	-16,9				
Renewable energy forms	75343	89606	104501	124880	158307	200185	274242	287081	306231	314663	325594	329900	334107	3,3	4,2	5,6	1,1	0,6	0,3
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	17,1	15,9	14,3	14,6	12,8	11,2	10,7	10,5	10,5						
Oil	38,0	39,1	38,2	37,1	35,8	34,9	34,5	33,8	33,1	33,0	32,7	32,4	32,5						
Natural gas	17,8	20,0	22,8	24,4	24,6	24,5	23,1	22,0	22,0	21,9	21,4	20,6	20,3						
Nuclear	12,2	13,4	14,1	14,1	13,5	13,4	12,4	12,9	13,6	14,7	15,1	16,1	16,0						
Renewable energy forms	4,5	5,4	6,1	6,8	8,9	11,3	15,8	16,9	18,6	19,4	20,1	20,4	20,9						
Gross Electricity Generation in GWh_e	**2562823**	**2712209**	**2991720**	**3274121**	**3409804**	**3546574**	**3640517**	**3805418**	**3847929**	**3979537**	**4149864**	**4296838**	**4422136**	**1,6**	**1,3**	**0,7**	**0,6**	**0,8**	**0,6**
Nuclear	794718	881662	944823	997519	926760	926106	839746	869707	894285	960227	991575	1079581	1120310	1,7	-0,2	-1,0	0,6	1,0	1,2
Hydro & wind	292648	330306	375545	378836	501838	681666	961159	1088750	1265410	1360184	1423751	1476774	1521210	2,5	2,9	6,7	2,8	1,2	0,7
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1981205	1938802	1839613	1846961	1688233	1659125	1734538	1740483	1780616	1,3	1,7	-0,7	-0,9	0,3	0,3
Fuel Inputs for Thermal Power Generation	**383492**	**362334**	**382613**	**424208**	**434149**	**419199**	**395821**	**398462**	**366416**	**347988**	**348479**	**340828**	**341596**	**0,0**	**1,3**	**-0,9**	**-0,8**	**-0,5**	**-0,2**
Solids	263837	230040	223012	229245	232666	212875	183435	184448	151829	127468	120362	117510	117828	-1,7	0,4	-2,3	-1,9	-2,3	-0,2
Oil (including refinery gas)	54404	51463	39294	29780	17108	14834	10440	12597	14510	16582	19540	22211	22538	-3,2	-8,0	-4,8	3,3	3,0	1,4
Gas	56754	67806	102408	134637	143376	136764	121316	112813	108299	112591	113268	109781	108512	6,1	3,4	-1,7	-1,1	0,4	-0,4
Biomass & Waste	5724	10033	14960	25901	35172	48839	74498	82039	84752	84065	87709	83670	85006	10,1	8,9	7,8	1,3	0,3	-0,3
Geothermal heat	2774	2992	2939	4645	5828	5888	6132	6564	7026	7283	7598	7656	7712	0,6	7,1	0,5	1,4	0,8	0,1
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0	0	0	0	0						
Fuel Input in other transformation proc.	**839073**	**814654**	**827098**	**842975**	**794312**	**793070**	**781338**	**760762**	**734148**	**723907**	**716872**	**711989**	**705504**	**-0,1**	**-0,4**	**-0,2**	**-0,6**	**-0,2**	**-0,2**
Refineries	679426	705954	735244	758152	718789	710799	691492	671673	645802	637512	631601	627440	623443	0,8	-0,2	-0,4	-0,7	-0,2	-0,1
Biofuels and hydrogen production	2	202	610	3129	12210	19254	29539	30956	33883	34869	35217	34918	34430	79,6	34,9	9,2	1,4	0,4	-0,2
District heating	32960	23240	19323	16212	15818	15954	15610	15606	15321	14660	13627	13260	12605	-5,2	-2,0	-0,1	-0,2	-1,2	-0,8
Others	126685	85258	71921	65482	47494	47063	44696	42526	39142	36866	36427	36370	35027	-5,5	-4,1	-0,6	-1,3	-0,7	-0,4
Energy Branch Consumption	**82379**	**88696**	**88176**	**96033**	**92227**	**89214**	**87026**	**83948**	**78533**	**76980**	**77640**	**78300**	**79205**	**0,7**	**0,5**	**-0,6**	**-1,0**	**-0,1**	**0,2**
Non-Energy Uses	**97931**	**110541**	**112495**	**117477**	**111506**	**113869**	**114247**	**112993**	**112051**	**111634**	**110888**	**110802**	**109755**	**1,4**	**-0,1**	**0,2**	**-0,2**	**-0,1**	**-0,1**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173676**	**1165867**	**1194269**	**1192588**	**1162259**	**1132334**	**1124045**	**1122968**	**1122824**	**1117870**	**0,4**	**0,5**	**0,2**	**-0,5**	**-0,1**	**0,0**
by sector																			
Industry	365650	328513	326949	326308	312396	318694	318594	314412	309335	308420	310729	314529	319011	-1,1	-0,5	0,2	-0,3	0,0	0,3
- energy intensive industries	234722	214526	213112	210991	193236	194483	192043	186759	181214	177671	176330	175619	174559	-1,0	-1,0	-0,1	-0,6	-0,3	-0,1
- other industrial sectors	130928	113987	113837	115317	119160	124211	126551	127653	128121	130749	134399	138910	144452	-1,4	0,5	0,6	0,1	0,5	0,7
Residential	264307	280418	286784	308104	308367	314355	311436	298549	293725	289410	287820	286019	282827	0,8	0,7	0,1	-0,6	-0,2	-0,2
Tertiary	158484	160442	159866	176859	175093	179553	174102	166450	160488	159442	158306	157840	154982	0,1	0,9	-0,1	-0,8	-0,1	-0,2
Transport	280269	300617	339389	362405	370012	381667	388455	382848	368786	366772	366112	364437	361049	1,9	0,9	0,5	-0,5	-0,1	-0,1
by fuel																			
Solids	125031	84977	61454	54486	47428	45437	42767	41332	37414	35479	34747	34421	33170	-6,9	-2,6	-1,0	-1,3	-0,7	-0,5
Oil	444429	456959	478882	495857	476445	468217	455645	437218	412596	406540	402918	400377	395425	0,7	-0,1	-0,4	-1,0	-0,2	-0,2
Gas	227902	245996	265552	283524	265034	267981	245890	224175	215074	202873	192677	183372	177348	1,5	0,0	-0,7	-1,3	-1,1	-0,8
Electricity	184145	193367	216403	237537	248377	259589	265527	277752	281973	291640	303424	313299	320859	1,6	1,4	0,7	0,6	0,7	0,6
Heat (from CHP and District Heating) [(A)]	48610	44616	40061	44441	59478	71405	76954	81702	83418	86483	87578	88771	89161	-1,9	4,0	2,6	0,8	0,5	0,2
Other	38592	44073	50640	57832	69105	81640	105806	100081	101858	101030	101624	102583	101907	2,8	3,2	4,4	-0,4	0,0	0,0
CO_2 Emissions (Mt of CO_2 - sec approach)	**4030,6**	**3800,1**	**3810,6**	**3946,6**	**3771,6**	**3629,2**	**3314,9**	**3178,8**	**2912,7**	**2723,9**	**2571,6**	**2448,2**	**2322,3**	**-0,6**	**-0,1**	**-1,3**	**-1,3**	**-1,2**	**-1,0**
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1365,2	1263,1	1061,4	1050,4	907,3	788,9	683,5	601,9	513,4	-1,2	0,3	-2,5	-1,6	-2,8	-2,8
Energy Branch	152,2	171,0	170,2	181,6	157,5	143,4	131,4	119,7	108,8	93,3	84,2	72,0	68,5	1,1	-0,8	-1,8	-1,9	-2,5	-2,0
Industry	781,4	678,1	623,0	581,9	490,8	468,2	440,6	415,3	393,4	375,1	367,1	361,1	360,6	-2,2	-2,4	-1,1	-1,1	-0,7	-0,2
Residential	499,4	481,6	466,2	486,7	465,3	457,3	417,8	375,2	354,2	337,7	321,8	308,8	292,0	-0,7	0,0	-1,1	-1,6	-1,0	-1,0
Tertiary	300,5	275,3	242,0	262,2	244,5	234,9	212,6	189,1	172,6	162,0	151,2	144,6	136,5	-2,1	0,1	-1,4	-2,1	-1,3	-1,0
Transport	812,7	872,9	988,5	1053,1	1048,3	1062,3	1051,0	1029,3	976,4	967,0	963,8	959,8	951,3	2,0	0,6	0,0	-0,7	-0,1	-0,1
CO_2 Emissions Index (1990=100)	**100,0**	**94,3**	**94,5**	**97,9**	**93,6**	**90,0**	**82,2**	**78,9**	**72,3**	**67,6**	**63,8**	**60,7**	**57,6**						
CO_2 Emissions (Mt of CO_2 - ref approach)	**4172,0**	**3950,7**	**3922,7**	**4087,6**	**3837,6**	**3695,5**	**3382,8**	**3244,5**	**2979,3**	**2788,5**	**2634,7**	**2509,7**	**2388,3**	**-0,6**	**-0,2**	**-1,3**	**-1,3**	**-1,2**	**-1,0**

EU27: Reference Low Economic Growth scenario — SUMMARY ENERGY BALANCE AND INDICATORS (B)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12503,7	13605,2	14595,0	15526,6	16426,8	17322,2	18267,5	19239,1	2,2	1,2	1,8	1,3	1,1	1,1
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	155,9	142,1	127,5	116,4	105,8	98,7	93,3	88,4	83,1	-1,8	-0,9	-2,0	-1,8	-1,3	-1,1
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,55	3,50	3,38	3,28	3,16	3,11	3,11	3,11	3,10	0,1	-0,1	-0,5	-0,7	-0,2	0,0
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6828	6985	7085	7349	7401	7643	7979	8289	8582	1,3	0,9	0,4	0,4	0,8	0,7
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,13	2,04	1,91	1,87	1,77	1,68	1,59	1,52	1,45	-0,9	-0,4	-1,1	-0,8	-1,1	-0,9
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,55	7,15	6,45	6,14	5,60	5,23	4,94	4,72	4,51	-0,8	-0,5	-1,6	-1,4	-1,2	-0,9
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	331,3	290,2	243,7	217,8	187,6	165,8	148,5	134,0	120,7	-2,7	-1,3	-3,0	-2,6	-2,3	-2,0
Import Dependency %	44,6	43,5	46,8	52,5	53,7	56,3	56,6	56,7	56,6	56,4	56,3	56,5	57,3						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	90,3	84,8	78,5	72,6	67,7	64,2	61,7	59,5	57,6	-2,6	-1,0	-1,4	-1,5	-0,9	-0,7
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,9	89,6	80,3	70,9	64,8	58,8	54,3	50,0	46,2	-1,3	-0,3	-1,9	-2,1	-1,8	-1,6
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	94,7	87,7	77,8	69,1	62,3	58,4	54,8	51,5	47,9	-2,3	-0,5	-1,9	-2,2	-1,3	-1,3
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	90,9	85,0	78,1	70,7	66,5	62,9	59,4	55,9	-0,2	-0,3	-1,3	-1,8	-1,2	-1,2
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,32	0,28	0,22	0,21	0,18	0,15	0,13	0,11	0,09	-2,1	-1,5	-3,5	-2,1	-3,5	-3,3
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,93	1,86	1,78	1,73	1,67	1,64	1,61	1,58	1,56	-0,7	-0,8	-0,8	-0,6	-0,4	-0,3
Industry	2,14	2,06	1,91	1,78	1,57	1,47	1,38	1,32	1,27	1,22	1,18	1,15	1,13	-1,1	-1,9	-1,3	-0,8	-0,7	-0,4
Residential	1,89	1,72	1,63	1,58	1,51	1,45	1,34	1,26	1,21	1,17	1,12	1,08	1,03	-1,5	-0,7	-1,2	-1,1	-0,8	-0,8
Tertiary	1,90	1,72	1,51	1,48	1,40	1,31	1,22	1,14	1,08	1,02	0,96	0,92	0,88	-2,2	-0,8	-1,3	-1,3	-1,2	-0,8
Transport	2,90	2,90	2,91	2,91	2,83	2,78	2,71	2,69	2,65	2,64	2,63	2,63	2,63	0,0	-0,3	-0,5	-0,2	-0,1	0,0
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654125**	**715732**	**820302**	**917001**	**1008635**	**1041998**	**1114218**	**1167080**	**1223532**	**1282130**	**1332260**		**2,3**	**2,1**	**1,0**	**0,9**	**0,9**
Nuclear energy			133923	134409	127038	126752	123736	113246	115835	122226	124174	132588	138575		-0,5	-0,3	-0,7	0,7	1,1
Renewable energy			112878	147262	209023	279278	397750	448906	522682	563776	591587	616938	643052		6,4	6,6	2,8	1,2	0,8
Hydro (pumping excluded)			99714	104505	107315	110765	114160	115440	117367	118744	119046	119875	121060		0,7	0,6	0,3	0,1	0,2
Wind			12793	40584	86153	140082	228571	263271	309575	329210	341594	352536	357648		21,0	10,2	3,1	1,0	0,5
Solar			371	2172	15307	27855	53352	67338	91599	111359	126122	139101	158252		45,1	13,3	5,6	3,2	2,3
Other renewables (tidal etc.)			0	1	249	575	1667	2857	4141	4463	4825	5425	6092			21,0	9,5	1,5	2,4
Thermal power			407324	434061	484241	510971	487149	479846	475701	481078	507771	532603	550632		1,7	0,1	-0,2	0,7	0,8
of which cogeneration units			75904	85934	100505	111834	115771	122900	127450	138698	154273	169250	172553		2,8	1,4	1,0	1,9	1,1
of which CCS units			0	0	0	0	5394	5434	6107	11077	25615	41330	60069				1,2	15,4	8,9
Solids fired			194165	186620	183870	182485	163133	146101	128524	114275	113957	110176	110793		-0,5	-1,2	-2,4	-1,2	-0,3
Gas fired			129444	167173	219348	238458	228127	224079	234770	255062	258866	245279	212265		5,4	0,4	0,3	1,0	-2,0
Oil fired			71058	62082	56070	47003	36127	41149	39971	38440	57337	95207	141825		-2,3	-4,3	1,0	3,7	9,5
Biomass-waste fired			12051	17502	24171	42238	58943	67641	71498	72330	76598	80921	84721		7,2	9,3	1,9	0,7	1,0
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	684	783	786	818	876	937	971	1013	1021	1028		2,6	0,4	1,4	0,8	0,1
Load factor for net electric capacities (%)			49,1	49,1	45,1	42,1	39,3	39,8	37,7	37,3	36,9	36,4	35,8						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,2	39,8	40,0	39,9	39,6	41,0	42,8	43,9	44,8						
CHP indicator (% of electricity from CHP)			11,4	11,7	15,0	17,8	18,8	18,8	18,6	20,2	21,4	22,3	22,0						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	1,4	1,4	1,6	2,8	5,7	8,6	12,1						
Non fossil fuels in electricity generation (%)			45,8	44,8	45,9	50,6	57,3	59,8	64,7	66,7	66,9	67,7	67,9						
- nuclear			31,6	30,5	27,2	26,1	23,1	22,9	23,2	24,1	23,9	25,1	25,3						
- renewable energy forms and industrial waste			14,2	14,3	18,7	24,5	34,2	37,0	41,5	42,5	43,0	42,5	42,5						
Indicators for renewables (excluding industrial waste) (%) [(B)]																			
RES in gross final energy demand (%)			7,6	8,6	11,4	14,7	20,4	21,9	24,1	24,9	25,7	25,9	26,4						
RES in transport (%)			0,5	1,4	4,3	6,6	10,1	10,9	12,6	13,1	13,3	13,3	13,3						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**7013,0**	**7503,5**	**7946,7**	**8344,0**	**8643,1**	**8964,8**	**9191,6**	**9398,3**	**1,9**	**1,0**	**1,4**	**1,1**	**0,7**	**0,5**
Public road transport	544,0	504,0	517,6	526,0	545,0	562,1	591,3	614,6	632,7	645,1	659,9	668,2	676,2	-0,5	0,5	0,8	0,7	0,4	0,2
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,1	5211,0	5505,7	5759,4	5986,6	6159,8	6340,8	6450,0	6539,2	2,4	0,9	1,2	0,8	0,6	0,3
Rail	472,5	421,7	447,9	461,0	482,5	515,6	555,5	596,2	631,8	664,9	701,9	729,8	754,6	-0,5	0,7	1,4	1,3	1,1	0,7
Aviation	317,3	351,3	456,9	527,3	576,9	683,0	808,0	932,1	1047,4	1127,1	1214,9	1295,5	1379,4	3,7	2,4	3,4	2,6	1,5	1,3
Inland navigation	45,8	44,4	41,7	39,5	40,8	41,2	42,9	44,5	45,5	46,3	47,4	48,0	48,8	-0,9	-0,2	0,5	0,6	0,4	0,3
Travel per person (km per capita)	10376	11127	12248	12756	13039	13813	14603	15347	16048	16601	17237	17732	18238	1,7	0,6	1,1	0,9	0,7	0,6
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2911,2**	**3038,4**	**3137,2**	**3212,2**	**3268,1**	**3311,5**	**3336,5**	**3334,5**	**1,7**	**1,9**	**1,3**	**0,6**	**0,3**	**0,1**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2137,7	2228,2	2301,2	2359,2	2402,5	2437,3	2459,4	2459,4	3,7	2,5	1,4	0,6	0,3	0,1
Rail	526,3	386,1	403,7	414,1	440,5	481,0	507,1	524,5	536,5	545,8	553,3	557,2	558,6	-2,6	0,9	1,4	0,6	0,3	0,1
Inland navigation	261,6	267,6	273,3	280,2	281,9	292,5	303,1	311,5	316,5	319,7	320,9	319,9	316,6	0,4	0,3	0,7	0,4	0,1	-0,1
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	233	223	215	207	199	191	183	173	-0,4	0,7	-0,5	-0,8	-0,8	-1,0
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**370012**	**381667**	**388455**	**382848**	**368786**	**366772**	**366112**	**364437**	**361049**	**1,9**	**0,9**	**0,5**	**-0,5**	**-0,1**	**-0,1**
Public road transport	5197	4732	4914	5039	5182	5223	5239	5161	5030	5003	4988	4835	4650	-0,6	0,5	0,1	-0,4	-0,1	-0,7
Private cars and motorcycles	154395	166321	182974	187736	186451	182339	180817	173226	163247	159731	158146	155069	152943	1,7	0,2	-0,3	-1,0	-0,3	-0,3
Trucks	74969	79037	90951	105104	111606	121467	123197	122945	120492	120737	120885	120408	119478	2,0	2,1	1,0	-0,2	0,0	-0,1
Rail	9560	9452	9600	9436	9597	9983	9722	9298	8103	7935	7972	7934	7843	0,0	0,0	0,1	-1,8	-0,2	-0,2
Aviation	29038	34112	45395	49703	51709	57141	63744	66294	65892	67281	67991	70062	70046	4,6	1,3	2,1	0,3	0,3	0,3
Inland navigation	7110	6963	5555	5386	5466	5514	5737	5924	6022	6085	6131	6129	6089	-2,4	-0,2	0,5	0,5	0,2	-0,1
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	35,5	33,8	31,3	28,6	27,3	26,3	25,5	24,7	0,2	-0,6	-1,2	-1,7	-0,8	-0,6
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,1	45,7	44,3	42,7	40,6	39,9	39,5	39,0	38,7	-0,2	-0,1	-0,4	-0,9	-0,3	-0,2

1bis. Current Policy Initiatives scenario

EU27: Current Policy Initiatives scenario — **SUMMARY ENERGY BALANCE AND INDICATORS (A)**

ktoe	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Production	**936047**	**950181**	**941860**	**900326**	**837026**	**805387**	**776345**	**746662**	**716019**	**722881**	**723028**	**725625**	**702833**	**0,1**	**-1,2**	**-0,7**	**-0,8**	**0,1**	**-0,3**
Solids	366477	277810	213423	196277	177948	167710	142792	133720	108664	102483	94040	98126	97033	-5,3	-1,8	-2,2	-2,7	-1,4	0,3
Oil	129551	171052	173006	134290	104398	74031	47982	39510	36057	31092	24091	15949	7609	2,9	-4,9	-7,5	-2,8	-4,0	-10,9
Natural gas	162447	188965	207559	188677	164866	129037	110504	91051	76179	65307	54304	39637	30443	2,5	-2,3	-3,9	-3,7	-3,3	-5,6
Nuclear	202589	223028	243761	257360	235016	237233	223904	211481	197877	217023	224567	232068	218790	1,9	-0,4	-0,5	-1,2	1,3	-0,3
Renewable energy sources	74984	89326	104111	123722	154799	197376	251162	270899	297242	306976	326026	339846	348958	3,3	4,0	5,0	1,7	0,9	0,7
Hydro	25101	28054	30374	26395	30008	30230	30742	31447	31950	32393	32885	33307	33634	1,9	-0,1	0,2	0,4	0,3	0,2
Biomass & Waste	46473	57201	67982	85129	102157	123309	146810	154243	159433	156911	160094	164043	162408	3,9	4,2	3,7	0,8	0,0	0,1
Wind	67	350	1913	6061	12781	26970	46373	54479	69420	76665	85809	91856	98027	39,8	20,9	13,8	4,1	2,1	1,3
Solar and others	153	274	421	807	3449	9398	18597	21678	26902	31099	37025	40331	44463	10,7	23,4	18,4	3,8	3,2	1,8
Geothermal	3190	3447	3421	5331	6404	7468	8640	9053	9537	9908	10213	10309	10427	0,7	6,5	3,0	1,0	0,7	0,2
Net Imports	**756079**	**738600**	**826299**	**986048**	**965395**	**1049565**	**977353**	**982714**	**969153**	**960489**	**952968**	**956662**	**970866**	**0,9**	**1,6**	**0,1**	**-0,1**	**-0,2**	**0,2**
Solids	81846	79338	98645	126639	102078	115497	95406	96317	86298	71531	59790	53306	55097	1,9	0,3	-0,7	-1,0	-3,6	-0,8
Oil	535645	512185	533039	599851	580911	609332	595279	593366	574554	568907	564756	564377	565740	0,0	0,9	0,2	-0,4	-0,2	0,0
- Crude oil and Feedstocks	508460	494000	513725	581995	578386	611451	607203	607062	591933	587692	585536	586758	590001	0,1	1,2	0,5	-0,3	-0,1	0,1
- Oil products	27185	18185	19314	17856	2525	-2119	-11924	-13696	-17379	-18786	-20781	-22380	-24262	-3,4	-18,4				
Natural gas	135121	145288	192531	257366	277819	318023	271055	280810	293286	303378	309596	316761	323814	3,6	3,7	-0,2	0,8	0,5	0,5
Electricity	3323	1508	1686	971	696	-540	-1990	-2558	-1672	-1689	-2228	-2318	-2616	-6,6	-8,5				
Renewable energy forms	144	279	397	1222	3891	7253	17603	14779	16687	18362	21055	24536	28832	10,7	25,6	16,3	-0,5	2,4	3,2
Gross Inland Consumption	**1660159**	**1662517**	**1723099**	**1825989**	**1752370**	**1802836**	**1700364**	**1674909**	**1629357**	**1626479**	**1618141**	**1623657**	**1614786**	**0,4**	**0,2**	**-0,3**	**-0,4**	**-0,1**	**0,0**
Solids	452940	364248	321007	319922	280026	283208	238198	230037	194962	174014	153830	151432	152130	-3,4	-1,4	-1,6	-2,0	-2,3	-0,1
Oil	631058	650858	658727	676859	635257	631246	589927	578409	554930	543281	531352	522826	516760	0,4	-0,4	-0,7	-0,6	-0,4	-0,3
Natural gas	294905	333268	393417	445998	442685	447060	381559	371862	369465	368685	363900	356397	354256	2,9	1,2	-1,5	-0,3	-0,2	-0,3
Nuclear	202589	223028	243761	257360	235016	237233	223904	211481	197877	217023	224567	232068	218790	1,9	-0,4	-0,5	-1,2	1,3	-0,3
Electricity	3323	1508	1686	971	696	-540	-1990	-2558	-1672	-1689	-2228	-2318	-2616	-6,6	-8,5				
Renewable energy forms	75343	89606	104501	124880	158690	204629	268766	285678	313796	325165	346720	363253	375464	3,3	4,3	5,4	1,6	1,0	0,8
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	16,0	15,7	14,0	13,7	12,0	10,7	9,5	9,3	9,4						
Oil	38,0	39,1	38,2	37,1	36,3	35,0	34,7	34,5	34,1	33,4	32,8	32,2	32,0						
Natural gas	17,8	20,0	22,8	24,4	25,3	24,8	22,4	22,2	22,7	22,7	22,5	22,0	21,9						
Nuclear	12,2	13,4	14,1	14,1	13,4	13,2	13,2	12,6	12,1	13,3	13,9	14,3	13,5						
Renewable energy forms	4,5	5,4	6,1	6,8	9,1	11,4	15,8	17,1	19,3	20,0	21,4	22,4	23,3						
Gross Electricity Generation in GWh_e	**2562823**	**2712209**	**2991720**	**3274121**	**3312980**	**3613745**	**3645321**	**3762072**	**3780339**	**3990186**	**4222325**	**4447319**	**4620421**	**1,6**	**1,0**	**1,0**	**0,4**	**1,1**	**0,9**
Nuclear	794718	881662	944823	997519	911418	920491	871965	833383	782075	864300	898050	944006	952038	1,7	-0,4	-0,4	-1,1	1,4	0,6
Hydro & wind	292648	330306	375545	378836	514979	698335	967118	1093798	1316289	1445535	1620977	1735525	1855756	2,5	3,2	6,5	3,1	2,1	1,4
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1886583	1994918	1806239	1834891	1681975	1680351	1703298	1767788	1812628	1,3	1,2	-0,4	-0,7	0,1	0,6
Fuel Inputs for Thermal Power Generation	**383492**	**362334**	**382613**	**424208**	**410755**	**427883**	**389444**	**392044**	**361342**	**350349**	**339566**	**339866**	**343621**	**0,0**	**0,7**	**-0,5**	**-0,7**	**-0,6**	**0,1**
Solids	263837	230040	223012	229245	208913	212061	172763	167428	136756	118877	100480	98977	99662	-1,7	-0,7	-1,9	-2,3	-3,0	-0,1
Oil (including refinery gas)	54404	51463	39294	29780	15695	15188	8979	12402	12388	15436	17387	20231	20607	-3,2	-8,8	-5,4	3,3	3,4	1,7
Gas	56754	67806	102408	134637	145390	142400	125116	122606	120044	123468	125568	121715	124120	6,1	3,6	-1,5	-0,4	0,5	-0,1
Biomass & Waste	5724	10033	14960	25901	35356	52271	76372	82943	85031	85162	88407	91143	91361	10,1	9,0	8,0	1,1	0,4	0,3
Geothermal heat	2774	2992	2939	4645	5400	5963	6213	6664	7122	7406	7724	7800	7872	0,6	6,3	1,4	1,4	0,8	0,2
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0	0	0	0	0						
Fuel Input in other transformation proc.	**839073**	**814654**	**827098**	**842975**	**793113**	**803071**	**776300**	**766396**	**746743**	**736376**	**724836**	**717189**	**711318**	**-0,1**	**-0,4**	**-0,2**	**-0,4**	**-0,3**	**-0,2**
Refineries	679426	705954	735244	758152	718218	720744	689515	679553	659477	649983	640382	632962	627528	0,8	-0,2	-0,4	-0,4	-0,3	-0,2
Biofuels and hydrogen production	2	202	610	3129	12209	19513	28618	30946	34309	34435	34686	35133	35769	79,6	34,9	8,9	1,8	0,1	0,3
District heating	32960	23240	19323	16212	15409	15322	13687	13190	13423	14265	13242	12207	11198	-5,2	-2,2	-1,2	-0,2	-0,1	-1,7
Others	126685	85258	71921	65482	47277	47493	44479	42707	39533	37694	36527	36887	36823	-5,5	-4,1	-0,6	-1,2	-0,8	0,1
Energy Branch Consumption	**82379**	**88696**	**88176**	**96033**	**91074**	**90307**	**85126**	**83086**	**77769**	**76037**	**75036**	**74997**	**74079**	**0,7**	**0,3**	**-0,7**	**-0,9**	**-0,4**	**-0,1**
Non-Energy Uses	**97931**	**110541**	**112495**	**117477**	**111510**	**115326**	**117845**	**118225**	**119183**	**120291**	**121266**	**122262**	**123092**	**1,4**	**-0,1**	**0,6**	**0,1**	**0,2**	**0,1**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173676**	**1160910**	**1214761**	**1157872**	**1148252**	**1136214**	**1138392**	**1141619**	**1151330**	**1156559**	**0,4**	**0,4**	**0,0**	**-0,2**	**0,0**	**0,1**
by sector																			
Industry	365650	328513	326949	326308	310965	322828	318673	315968	314300	318427	327826	338492	350391	-1,1	-0,5	0,2	-0,1	0,4	0,7
- energy intensive industries	234722	214526	213112	210991	192086	196730	191465	187221	183614	182826	184911	187198	189754	-1,0	-1,0	0,0	-0,4	0,1	0,3
- other industrial sectors	130928	113987	113837	115317	118878	126099	127208	128747	130686	135602	142915	151294	160638	-1,4	0,4	0,7	0,3	0,9	1,2
Residential	264307	280418	286784	308104	306404	320964	289275	282307	281757	281704	280210	280297	277205	0,8	0,7	-0,6	-0,3	-0,1	-0,1
Tertiary	158484	160442	159866	176859	173576	183822	167174	165382	164934	166522	167126	168815	168144	0,1	0,8	-0,4	-0,1	0,1	0,1
Transport	280269	300617	339389	362405	369964	387147	382749	384595	375223	371739	366457	363726	360820	1,9	0,9	0,3	-0,2	-0,2	-0,2
by fuel																			
Solids	125031	84977	61454	54486	47496	47065	43019	40725	37186	34923	34368	34026	33887	-6,9	-2,5	-1,0	-1,4	-0,8	-0,1
Oil	444429	456959	478882	495857	477192	477043	445487	437131	418452	409529	399224	392154	383567	0,7	0,0	-0,7	-0,6	-0,5	-0,4
Gas	227902	245996	265552	283524	268367	273535	226044	214901	212684	205436	198786	196074	192096	1,5	0,1	-1,7	-0,6	-0,7	-0,3
Electricity	184145	193367	216403	237537	241828	264545	267064	275001	278517	294300	310981	327092	339827	1,6	1,1	1,0	0,4	1,1	0,9
Heat (from CHP and District Heating) [(A)]	48610	44616	40061	44441	57335	71257	77936	82605	85099	91632	93998	96950	98920	-1,9	3,7	3,1	0,9	1,0	0,5
Other	38592	44073	50640	57832	68692	81316	98321	97888	104276	102572	104261	105034	108261	2,8	3,1	3,7	0,6	0,0	0,4
CO_2 Emissions (Mt of CO_2 - sec approach)	**4030,6**	**3800,1**	**3810,6**	**3946,6**	**3686,1**	**3688,6**	**3211,3**	**3122,7**	**2904,1**	**2753,4**	**2536,8**	**2414,6**	**2367,4**	**-0,6**	**-0,3**	**-1,4**	**-1,0**	**-1,3**	**-0,7**
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1269,1	1273,8	1035,4	1017,4	886,4	803,7	647,7	564,8	553,3	-1,2	-0,4	-2,0	-1,5	-3,1	-1,6
Energy Branch	152,2	171,0	170,2	181,6	157,4	146,3	130,1	121,3	110,3	94,8	82,6	68,6	68,3	1,1	-0,8	-1,9	-1,6	-2,8	-1,9
Industry	781,4	678,1	623,0	581,9	497,8	483,8	442,1	419,0	399,4	383,3	382,1	391,4	399,3	-2,2	-2,2	-1,2	-1,0	-0,4	0,4
Residential	499,4	481,6	466,2	486,7	467,3	467,1	380,6	351,3	341,7	332,1	318,6	308,7	293,1	-0,7	0,0	-2,0	-1,1	-0,7	-0,8
Tertiary	300,5	275,3	242,0	262,2	246,3	240,1	187,0	180,9	178,7	173,8	166,7	162,6	156,8	-2,1	0,2	-2,7	-0,5	-0,7	-0,6
Transport	812,7	872,9	988,5	1053,1	1048,2	1077,6	1036,1	1032,8	987,7	965,8	939,1	918,6	896,6	2,0	0,6	-0,1	-0,5	-0,5	-0,5
CO_2 Emissions Index (1990=100)	**100,0**	**94,3**	**94,5**	**97,9**	**91,5**	**91,5**	**79,7**	**77,5**	**72,1**	**68,3**	**62,9**	**59,9**	**58,7**						
CO_2 Emissions (Mt of CO_2 - ref approach)	**4172,0**	**3950,7**	**3922,7**	**4087,6**	**3753,2**	**3756,3**	**3280,2**	**3189,8**	**2972,4**	**2819,5**	**2601,4**	**2477,3**	**2434,3**	**-0,6**	**-0,4**	**-1,3**	**-1,0**	**-1,3**	**-0,7**

EU27: Current Policy Initiatives scenario														SUMMARY ENERGY BALANCE AND INDICATORS (B)					
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12750,3	14164,0	15503,7	16824,7	18157,1	19527,9	21002,9	22560,0	2,2	1,2	2,2	1,7	1,5	1,5
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	153,9	141,4	120,0	108,0	96,8	89,6	82,9	77,3	71,6	-1,8	-1,0	-2,5	-2,1	-1,5	-1,5
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,51	3,55	3,31	3,23	3,13	3,12	3,11	3,13	3,13	0,1	-0,2	-0,6	-0,5	-0,1	0,1
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6634	7117	7094	7265	7271	7664	8118	8580	8966	1,3	0,6	0,7	0,2	1,1	1,0
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,10	2,05	1,89	1,86	1,78	1,69	1,57	1,49	1,47	-0,9	-0,5	-1,1	-0,6	-1,3	-0,7
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,38	7,26	6,25	6,03	5,59	5,29	4,88	4,66	4,59	-0,8	-0,7	-1,7	-1,1	-1,3	-0,6
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	323,7	289,3	226,7	201,4	172,6	151,6	129,9	115,0	104,9	-2,7	-1,5	-3,5	-2,7	-2,8	-2,1
Import Dependency %	44,6	43,5	46,8	52,5	53,6	56,6	55,7	56,8	57,5	57,1	56,9	56,9	58,0						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	89,9	84,6	75,6	68,9	63,7	60,1	57,8	55,8	54,1	-2,6	-1,1	-1,7	-1,7	-1,0	-0,7
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,3	89,7	73,1	65,9	61,0	56,0	51,9	47,9	44,4	-1,3	-0,4	-2,7	-1,8	-1,6	-1,5
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	93,9	88,0	71,7	64,5	59,1	55,1	51,2	47,9	44,3	-2,3	-0,6	-2,7	-1,9	-1,4	-1,5
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	90,4	80,5	73,9	66,4	61,0	55,9	51,6	47,6	-0,2	-0,3	-1,8	-1,9	-1,7	-1,6
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,31	0,27	0,22	0,21	0,18	0,15	0,12	0,10	0,09	-2,1	-2,0	-3,4	-2,0	-4,1	-2,3
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,95	1,87	1,77	1,73	1,68	1,63	1,58	1,55	1,51	-0,7	-0,7	-1,0	-0,5	-0,6	-0,5
Industry	2,14	2,06	1,91	1,78	1,60	1,50	1,39	1,33	1,27	1,20	1,17	1,16	1,14	-1,1	-1,7	-1,4	-0,9	-0,9	-0,2
Residential	1,89	1,72	1,63	1,58	1,53	1,46	1,32	1,24	1,21	1,18	1,14	1,10	1,06	-1,5	-0,6	-1,5	-0,8	-0,6	-0,7
Tertiary	1,90	1,72	1,51	1,48	1,42	1,31	1,12	1,09	1,08	1,04	1,00	0,96	0,93	-2,2	-0,6	-2,3	-0,3	-0,8	-0,7
Transport	2,90	2,90	2,91	2,91	2,83	2,78	2,71	2,69	2,63	2,60	2,56	2,53	2,48	0,0	-0,3	-0,5	-0,3	-0,3	-0,3
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654168**	**715466**	**821506**	**927968**	**1013372**	**1045670**	**1123061**	**1197316**	**1311405**	**1414578**	**1501619**		**2,3**	**2,1**	**1,0**	**1,6**	**1,4**
Nuclear energy			133966	134452	131393	125743	124707	105768	101557	106734	110775	116332	116922		-0,2	-0,5	-2,0	0,9	0,5
Renewable energy			112878	147262	206776	279103	393538	446051	534888	589105	671048	725267	783812		6,2	6,6	3,1	2,3	1,6
Hydro (pumping excluded)			99714	104505	107315	111368	114584	116108	117567	119359	120037	121142	122241		0,7	0,7	0,3	0,2	0,2
Wind			12793	40584	83905	139251	223516	257880	317537	345380	381920	406916	431501		20,7	10,3	3,6	1,9	1,2
Solar			371	2172	15307	27909	53760	69195	95654	120062	164310	191934	223547		45,1	13,4	5,9	5,6	3,1
Other renewables (tidal etc.)			0	1	249	575	1678	2868	4130	4304	4781	5276	6523			21,0	9,4	1,5	3,2
Thermal power			407324	433752	483337	523122	495127	493851	486617	501477	529582	572979	600885		1,7	0,2	-0,2	0,8	1,3
of which cogeneration units			76323	85573	98206	117216	121639	129744	136540	151746	168594	189716	200582		2,6	2,2	1,2	2,1	1,8
of which CCS units			0	0	0	0	2711	2711	2858	7130	21494	33685	38601				0,5	22,4	6,0
Solids fired			194165	186620	183632	182385	157369	141203	123174	109336	106993	107732	103963		-0,6	-1,5	-2,4	-1,4	-0,3
Gas fired			129444	166863	218425	248820	240901	246498	256144	286580	311450	340496	365540		5,4	1,0	0,6	2,0	1,6
Oil fired			71058	62082	55989	46686	35662	35490	32806	30468	31211	35959	37959		-2,4	-4,4	-0,8	-0,5	2,0
Biomass-waste fired			12051	17502	24564	44434	60366	69771	73543	74105	78898	87751	92374		7,4	9,4	2,0	0,7	1,6
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	686	727	796	829	889	950	987	1030	1040	1049		1,9	1,3	1,4	0,8	0,2
Load factor for net electric capacities (%)			49,1	49,1	43,8	42,4	39,3	39,3	36,9	36,5	35,2	34,3	33,6						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,5	40,1	39,9	40,3	40,0	41,2	43,1	44,7	45,4						
CHP indicator (% of electricity from CHP)			11,4	11,7	14,9	19,0	20,2	20,9	21,0	23,0	24,4	25,3	25,4						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	0,7	0,7	0,8	1,8	4,9	7,2	7,6						
Non fossil fuels in electricity generation (%)			45,8	44,8	47,3	50,3	58,4	59,8	64,3	66,4	68,3	68,9	69,4						
- nuclear			31,6	30,5	27,5	25,5	23,9	22,2	20,7	21,7	21,3	21,2	20,6						
- renewable energy forms and industrial waste			14,2	14,3	19,8	24,9	34,5	37,7	43,7	44,8	47,0	47,7	48,8						
Indicators for renewables (excluding industrial waste) (%) [(B)]																			
RES in gross final energy demand (%)			7,6	8,6	11,4	14,7	20,6	22,1	24,7	25,5	27,0	27,9	29,0						
RES in transport (%)			0,5	1,4	4,3	6,6	10,0	10,9	13,1	14,6	16,3	18,1	19,9						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**7131,9**	**7500,5**	**7937,8**	**8374,0**	**8704,3**	**8990,6**	**9239,0**	**9449,4**	**1,9**	**1,0**	**1,4**	**1,1**	**0,7**	**0,5**
Public road transport	544,0	504,0	517,6	526,0	545,0	573,7	622,1	629,4	642,5	655,1	667,8	677,9	685,0	-0,5	0,5	1,3	0,3	0,4	0,3
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,0	5288,2	5442,3	5707,8	5975,4	6199,1	6358,1	6487,7	6566,1	2,4	0,9	1,1	0,9	0,6	0,3
Rail	472,5	421,7	447,9	461,0	482,5	524,8	567,5	606,6	642,7	678,6	714,3	744,4	767,6	-0,5	0,7	1,6	1,3	1,1	0,7
Aviation	317,3	351,3	456,9	527,3	576,9	702,8	824,6	948,7	1066,9	1124,0	1202,0	1279,8	1380,8	3,7	2,4	3,6	2,6	1,2	1,4
Inland navigation	45,8	44,4	41,7	39,5	40,8	42,5	43,9	45,3	46,5	47,5	48,4	49,2	49,8	-0,9	-0,2	0,7	0,6	0,4	0,3
Travel per person (km per capita)	10376	11127	12248	12756	13038	14047	14597	15329	16106	16718	17286	17823	18337	1,7	0,6	1,1	1,0	0,7	0,6
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2952,2**	**3034,2**	**3216,0**	**3392,2**	**3540,0**	**3661,9**	**3765,9**	**3842,6**	**1,7**	**1,9**	**1,3**	**1,1**	**0,8**	**0,5**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2164,4	2188,8	2327,7	2468,1	2583,2	2675,6	2756,1	2814,6	3,7	2,5	1,2	1,2	0,8	0,5
Rail	526,3	386,1	403,7	414,1	440,5	488,9	528,8	556,7	580,4	602,6	623,7	641,0	655,9	-2,6	0,9	1,8	0,9	0,7	0,5
Inland navigation	261,6	267,6	273,3	280,2	281,9	299,0	316,6	331,7	343,8	354,2	362,6	368,7	372,1	0,4	0,3	1,2	0,8	0,5	0,3
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	232	214	207	202	195	188	179	170	-0,4	0,7	-0,9	-0,6	-0,7	-1,0
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**369964**	**387147**	**382749**	**384595**	**375223**	**371739**	**366457**	**363726**	**360820**	**1,9**	**0,9**	**0,3**	**-0,2**	**-0,2**	**-0,2**
Public road transport	5197	4732	4914	5039	5182	5315	5453	5220	5049	4935	4857	4717	4541	-0,6	0,5	0,5	-0,8	-0,4	-0,7
Private cars and motorcycles	154395	166321	182974	187736	186407	184711	175412	172112	164284	158346	151677	146045	141786	1,7	0,2	-0,6	-0,7	-0,8	-0,7
Trucks	74969	79037	90951	105104	111606	123125	121102	124119	124184	126725	127901	128575	129498	2,0	2,1	0,8	0,3	0,3	0,1
Rail	9560	9452	9600	9436	9594	10156	10082	9695	8533	8440	8568	8620	8605	0,0	0,0	0,5	-1,7	0,0	0,0
Aviation	29038	34112	45395	49703	51709	58141	64727	67225	66767	66741	66784	69024	69623	4,6	1,3	2,3	0,3	0,0	0,4
Inland navigation	7110	6963	5555	5386	5466	5699	5973	6224	6405	6552	6671	6744	6766	-2,4	-0,2	0,9	0,7	0,4	0,1
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	35,4	33,3	31,3	28,7	26,9	25,3	24,3	23,3	0,2	-0,6	-1,3	-1,5	-1,2	-0,8
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,0	45,7	43,9	42,2	39,7	38,8	37,9	37,1	36,6	-0,2	-0,1	-0,5	-1,0	-0,5	-0,4

2. Energy Efficiency scenario

EU27: Energy efficiency														SUMMARY ENERGY BALANCE AND INDICATORS (A)					
ktoe	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**'90-'00**	**'00-'10**	**'10-'20**	**'20-'30**	**'30-'40**	**'40-'50**
																Annual % Change			
Production	**936047**	**950181**	**941860**	**900326**	**833839**	**803043**	**761596**	**694780**	**659682**	**659971**	**677363**	**685507**	**680022**	**0,1**	**-1,2**	**-0,9**	**-1,4**	**0,3**	**0,0**
Solids	366477	277810	213423	196277	177968	165896	132685	105933	84105	61497	48888	45343	41400	-5,3	-1,8	-2,9	-4,5	-5,3	-1,6
Oil	129551	171052	173006	134290	104398	73498	46081	34968	31144	22909	14606	6974	2193	2,9	-4,9	-7,9	-3,8	-7,3	-17,3
Natural gas	162447	188965	207559	188677	164866	129035	110135	89779	73329	60554	48415	33392	23763	2,5	-2,3	-4,0	-4,0	-4,1	-6,9
Nuclear	202589	223028	243761	257360	235016	237212	217631	187614	161520	165771	165576	157847	146133	1,9	-0,4	-0,8	-2,9	0,2	-1,2
Renewable energy sources	74984	89326	104111	123722	151591	197402	255065	276486	309583	349241	399878	441951	466532	3,3	3,8	5,3	2,0	2,6	1,6
Hydro	25101	28054	30374	26395	30008	30262	30768	31520	32079	32558	33059	33517	33906	1,9	-0,1	0,3	0,4	0,3	0,3
Biomass & Waste	46473	57201	67982	85129	98969	122484	146500	151294	154860	177498	203668	227210	235869	3,9	3,8	4,0	0,6	2,8	1,5
Wind	67	350	1913	6061	12781	27714	50673	61151	80495	90167	105631	115095	122373	39,8	20,9	14,8	4,7	2,8	1,5
Solar and others	153	274	421	807	3436	9426	18321	22558	29364	35042	42746	49933	57105	10,7	23,3	18,2	4,8	3,8	2,9
Geothermal	3190	3447	3421	5331	6398	7515	8803	9963	12785	13977	14775	16196	17279	0,7	6,5	3,2	3,8	1,5	1,6
Net Imports	**756079**	**738600**	**826299**	**986048**	**969505**	**1045609**	**935509**	**869497**	**843906**	**748776**	**638784**	**540949**	**447418**	**0,9**	**1,6**	**-0,4**	**-1,0**	**-2,7**	**-3,5**
Solids	81846	79338	98645	126639	103139	114716	90982	66752	47554	25532	10900	787	2967	1,9	0,4	-1,2	-6,3	-13,7	-12,2
Oil	535645	512185	533039	599851	580690	607132	577878	538823	515852	442342	350767	255642	190463	0,0	0,9	0,0	-1,1	-3,8	-5,9
- Crude oil and Feedstocks	508460	494000	513725	581995	578257	599933	574739	540765	519973	449730	362486	278648	213455	0,1	1,2	-0,1	-1,0	-3,5	-5,2
- Oil products	27185	18185	19314	17856	2433	7199	3139	-1942	-4121	-7388	-11719	-23005	-22993	-3,4	-18,7	2,6			
Natural gas	135121	145288	192531	257366	277990	316766	254933	258021	274177	272660	266365	268387	232950	3,6	3,7	-0,9	0,7	-0,3	-1,3
Electricity	3323	1508	1686	971	696	-620	-2172	-2767	-2085	-2423	-2391	-2221	-2631	-6,6	-8,5				
Renewable energy forms	144	279	397	1222	6989	7615	13889	8669	8409	10664	13142	18355	23669	10,7	33,2	7,1	-4,9	4,6	6,1
Gross Inland Consumption	**1660159**	**1662517**	**1723099**	**1825989**	**1753292**	**1796536**	**1644191**	**1511566**	**1451696**	**1359670**	**1269261**	**1181523**	**1084235**	**0,4**	**0,2**	**-0,6**	**-1,2**	**-1,3**	**-1,6**
Solids	452940	364248	321007	319922	281108	280612	223666	172685	131659	87029	59788	46130	44367	-3,4	-1,3	-2,3	-5,2	-7,6	-2,9
Oil	631058	650858	658727	676859	635036	628513	571044	521079	495657	419240	326444	232336	167513	0,4	-0,4	-1,1	-1,4	-4,1	-6,5
Natural gas	294905	333268	393417	445998	442856	445801	365068	347800	347506	333214	314780	301779	256714	2,9	1,2	-1,9	-0,5	-1,0	-2,0
Nuclear	202589	223028	243761	257360	235016	237212	217631	187614	161520	165771	165576	157847	146133	1,9	-0,4	-0,8	-2,9	0,2	-1,2
Electricity	3323	1508	1686	971	696	-620	-2172	-2767	-2085	-2423	-2391	-2221	-2631	-6,6	-8,5				
Renewable energy forms	75343	89606	104501	124880	158580	205017	268954	285155	317439	356839	405063	445653	472139	3,3	4,3	5,4	1,7	2,5	1,5
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	16,0	15,6	13,6	11,4	9,1	6,4	4,7	3,9	4,1						
Oil	38,0	39,1	38,2	37,1	36,2	35,0	34,7	34,5	34,1	30,8	25,7	19,7	15,4						
Natural gas	17,8	20,0	22,8	24,4	25,3	24,8	22,2	23,0	23,9	24,5	24,8	25,5	23,7						
Nuclear	12,2	13,4	14,1	14,1	13,4	13,2	13,2	12,4	11,1	12,2	13,0	13,4	13,5						
Renewable energy forms	4,5	5,4	6,1	6,8	9,0	11,4	16,4	18,9	21,9	26,2	31,9	37,7	43,5						
Gross Electricity Generation in GWh_e	**2562823**	**2712209**	**2991720**	**3274121**	**3319449**	**3587278**	**3554658**	**3441083**	**3444401**	**3644175**	**3966432**	**4189457**	**4280835**	**1,6**	**1,0**	**0,7**	**-0,3**	**1,4**	**0,8**
Nuclear	794718	881662	944823	997519	911418	920404	846514	734218	639274	659717	661427	634217	608141	1,7	-0,4	-0,7	-2,8	0,3	-0,8
Hydro & wind	292648	330306	375545	378836	514979	707557	1017720	1177498	1473125	1649559	1912200	2105358	2269402	2,5	3,2	7,0	3,8	2,6	1,7
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1893052	1959318	1690425	1529367	1332002	1334900	1392805	1449882	1403292	1,3	1,3	-1,1	-2,4	0,4	0,1
Fuel Inputs for Thermal Power Generation	**383492**	**362334**	**382613**	**424208**	**412218**	**422207**	**367293**	**329297**	**295031**	**283734**	**282175**	**281605**	**269007**	**0,0**	**0,7**	**-1,1**	**-2,2**	**-0,4**	**-0,5**
Solids	263837	230040	223012	229245	209766	210376	158208	111997	75238	45028	30014	32184	37868	-1,7	-0,6	-2,8	-7,2	-8,8	2,4
Oil (including refinery gas)	54404	51463	39294	29780	15651	13381	8038	7615	7868	8538	7631	5403	380	-3,2	-8,8	-6,4	-0,2	-0,3	-25,9
Gas	56754	67806	102408	134637	145862	139967	117729	117389	112273	122652	124658	118231	105581	6,1	3,6	-2,1	-0,5	1,1	-1,6
Biomass & Waste	5724	10033	14960	25901	35540	52481	76900	85207	89700	96904	108643	113964	113081	10,1	9,0	8,0	1,6	1,9	0,4
Geothermal heat	2774	2992	2939	4645	5400	6002	6418	7089	9951	10612	11229	11824	12096	0,6	6,3	1,7	4,5	1,2	0,7
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0	0	0	0	0						
Fuel Input in other transformation proc.	**839073**	**814654**	**827098**	**842975**	**793734**	**792139**	**742125**	**692832**	**665908**	**588045**	**492738**	**389690**	**316019**	**-0,1**	**-0,4**	**-0,7**	**-1,1**	**-3,0**	**-4,3**
Refineries	679426	705954	735244	758152	718088	708691	655435	609166	583170	502456	402373	299193	221469	0,8	-0,2	-0,9	-1,2	-3,6	-5,8
Biofuels and hydrogen production	2	202	610	3129	12208	19510	26660	24758	24625	40526	57665	73263	85684	79,6	34,9	8,1	-0,8	8,9	4,0
District heating	32960	23240	19323	16212	15967	15982	13707	13042	12473	9350	7007	5001	3072	-5,2	-1,9	-1,5	-0,9	-5,6	-7,9
Others	126685	85258	71921	65482	47470	47956	46323	45867	45640	35714	25692	12234	5794	-5,5	-4,1	-0,2	-0,1	-5,6	-13,8
Energy Branch Consumption	**82379**	**88696**	**88176**	**96033**	**91099**	**89852**	**82278**	**75017**	**70319**	**64303**	**59086**	**59346**	**55593**	**0,7**	**0,3**	**-1,0**	**-1,6**	**-1,7**	**-0,6**
Non-Energy Uses	**97931**	**110541**	**112495**	**117477**	**111500**	**115323**	**118064**	**119577**	**121352**	**118886**	**116180**	**106083**	**98084**	**1,4**	**-0,1**	**0,6**	**0,3**	**-0,4**	**-1,7**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173676**	**1160767**	**1212131**	**1120527**	**1044943**	**1024697**	**954176**	**877444**	**807998**	**738230**	**0,4**	**0,4**	**-0,4**	**-0,9**	**-1,5**	**-1,7**
by sector																			
Industry	365650	328513	326949	326308	310910	322853	317442	316773	317290	303896	294495	276110	259502	-1,1	-0,5	0,2	0,0	-0,7	-1,3
- energy intensive industries	234722	214526	213112	210991	192094	196880	191006	188606	186913	175155	165311	150100	136307	-1,0	-1,0	-0,1	-0,2	-1,2	-1,9
- other industrial sectors	130928	113987	113837	115317	118816	125973	126437	128167	130376	128742	129184	126010	123194	-1,4	0,4	0,6	0,3	-0,1	-0,5
Residential	264307	280418	286784	308104	306282	320006	275661	248067	240692	224271	205576	188243	165480	0,8	0,7	-1,0	-1,3	-1,6	-2,1
Tertiary	158484	160442	159866	176859	173610	182117	158198	133819	130461	116183	102818	93756	84424	0,1	0,8	-0,9	-1,9	-2,4	-2,0
Transport	280269	300617	339389	362405	369965	387155	369225	346283	336253	309827	274555	249888	228825	1,9	0,9	0,0	-0,9	-2,0	-1,8
by fuel																			
Solids	125031	84977	61454	54486	47354	44926	40766	35674	30340	20573	14313	6593	2733	-6,9	-2,6	-1,5	-2,9	-7,2	-15,3
Oil	444429	456959	478882	495857	476981	476342	428033	386634	363986	299457	222062	158764	115466	0,7	0,0	-1,1	-1,6	-4,8	-6,3
Gas	227902	245996	265552	283524	267988	275277	219884	200299	204484	178877	150969	127025	91728	1,5	0,1	-2,0	-0,7	-3,0	-4,9
Electricity	184145	193367	216403	237537	242288	262641	261006	255066	258178	268371	280557	280314	275498	1,6	1,1	0,7	-0,1	0,8	-0,2
Heat (from CHP and District Heating) [(A)]	48610	44616	40061	44441	57863	72183	77278	79968	80195	81302	80089	77103	74105	-1,9	3,7	2,9	0,4	0,0	-0,8
Other	38592	44073	50640	57832	68292	80762	93560	87302	87515	105596	129454	158199	178701	2,8	3,0	3,2	-0,7	4,0	3,3
CO_2 Emissions (Mt of CO_2 - sec approach)	**4030,6**	**3800,1**	**3810,6**	**3946,6**	**3690,0**	**3666,5**	**3062,8**	**2666,1**	**2419,0**	**1945,1**	**1429,3**	**967,6**	**628,5**	**-0,6**	**-0,3**	**-1,8**	**-2,3**	**-5,1**	**-7,9**
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1275,0	1258,0	963,2	772,0	609,0	456,6	283,6	118,6	26,9	-1,2	-0,4	-2,8	-4,5	-7,4	-21,0
Energy Branch	152,2	171,0	170,2	181,6	157,2	145,6	126,9	110,4	102,9	76,9	59,4	43,5	27,2	1,1	-0,8	-2,1	-2,1	-5,4	-7,5
Industry	781,4	678,1	623,0	581,9	497,7	480,4	441,8	428,5	426,1	360,9	304,4	233,9	167,5	-2,2	-2,2	-1,2	-0,4	-3,3	-5,8
Residential	499,4	481,6	466,2	486,7	466,4	465,5	360,8	298,8	285,1	230,4	165,8	114,5	62,7	-0,7	0,0	-2,5	-2,3	-5,3	-9,3
Tertiary	300,5	275,3	242,0	262,2	245,5	239,4	180,9	151,3	146,4	119,5	87,9	59,3	34,9	-2,1	0,1	-3,0	-2,1	-5,0	-8,8
Transport	812,7	872,9	988,5	1053,1	1048,2	1077,6	989,2	905,1	849,5	700,8	528,3	397,8	309,3	2,0	0,6	-0,6	-1,5	-4,6	-5,2
CO_2 Emissions Index (1990=100)	**100,0**	**94,3**	**94,5**	**97,9**	**91,5**	**91,0**	**76,0**	**66,1**	**60,0**	**48,3**	**35,5**	**24,0**	**15,6**						
CO_2 Emissions (Mt of CO_2 - ref approach)	**4172,0**	**3950,7**	**3922,7**	**4087,6**	**3757,3**	**3735,2**	**3129,3**	**2730,3**	**2485,1**	**2006,8**	**1494,1**	**1053,4**	**727,7**	**-0,6**	**-0,4**	**-1,8**	**-2,3**	**-5,0**	**-6,9**

EU27: Energy efficiency														SUMMARY ENERGY BALANCE AND INDICATORS (B)					
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
																Annual % Change			
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12750,3	14164,0	15503,7	16824,7	18157,1	19527,9	21002,9	22560,0	2,2	1,2	2,2	1,7	1,5	1,5
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	154,0	140,9	116,1	97,5	86,3	74,9	65,0	56,3	48,1	-1,8	-1,0	-2,8	-2,9	-2,8	-3,0
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,51	3,54	3,20	2,92	2,79	2,61	2,44	2,28	2,10	0,1	-0,2	-0,9	-1,4	-1,3	-1,5
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6647	7065	6918	6645	6625	6999	7626	8082	8307	1,3	0,7	0,4	-0,4	1,4	0,9
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,10	2,04	1,86	1,76	1,67	1,43	1,13	0,82	0,58	-0,9	-0,5	-1,2	-1,1	-3,8	-6,4
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,39	7,22	5,96	5,15	4,65	3,74	2,75	1,87	1,22	-0,8	-0,7	-2,1	-2,4	-5,1	-7,8
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	324,1	287,6	216,2	172,0	143,8	107,1	73,2	46,1	27,9	-2,7	-1,5	-4,0	-4,0	-6,5	-9,2
Import Dependency %	44,6	43,5	46,8	52,5	53,8	56,6	55,1	55,6	56,1	53,2	48,5	44,1	39,7						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	89,9	84,6	75,3	69,1	64,3	57,4	52,0	45,5	40,0	-2,6	-1,1	-1,8	-1,6	-2,1	-2,6
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,2	89,4	69,7	57,9	52,1	44,6	38,1	32,2	26,5	-1,3	-0,4	-3,2	-2,9	-3,1	-3,6
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	93,9	87,1	67,9	52,2	46,7	38,5	31,5	26,6	22,2	-2,3	-0,6	-3,2	-3,7	-3,9	-3,4
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	90,4	77,6	66,5	59,5	50,8	41,9	35,4	30,2	-0,2	-0,3	-2,2	-2,6	-3,5	-3,2
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,31	0,27	0,21	0,17	0,13	0,10	0,06	0,02	0,01	-2,1	-1,9	-3,9	-4,3	-8,3	
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,95	1,87	1,76	1,71	1,67	1,48	1,24	1,00	0,78	-0,7	-0,7	-1,0	-0,6	-2,9	-4,5
Industry	2,14	2,06	1,91	1,78	1,60	1,49	1,39	1,35	1,34	1,19	1,03	0,85	0,65	-1,1	-1,7	-1,4	-0,4	-2,6	-4,6
Residential	1,89	1,72	1,63	1,58	1,52	1,45	1,31	1,20	1,18	1,03	0,81	0,61	0,38	-1,5	-0,7	-1,5	-1,0	-3,8	-7,3
Tertiary	1,90	1,72	1,51	1,48	1,41	1,31	1,14	1,13	1,12	1,03	0,85	0,63	0,41	-2,2	-0,7	-2,1	-0,2	-2,7	-7,0
Transport	2,90	2,90	2,91	2,91	2,83	2,78	2,68	2,61	2,53	2,26	1,92	1,59	1,35	0,0	-0,3	-0,6	-0,6	-2,7	-3,5
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654168**	**715466**	**821516**	**922175**	**1012749**	**1024363**	**1111329**	**1171937**	**1305302**	**1401647**	**1472585**		**2,3**	**2,1**	**0,9**	**1,6**	**1,2**
Nuclear energy			133966	134452	131393	125743	123107	100140	81678	83169	84304	83228	78908		-0,2	-0,6	-4,0	0,3	-0,7
Renewable energy			112878	147262	206776	281934	409965	475929	604380	689196	812765	912993	1011756		6,2	7,1	4,0	3,0	2,2
Hydro (pumping excluded)			99714	104505	107315	111511	114720	116661	118615	120810	121774	123301	125416		0,7	0,7	0,3	0,3	0,3
Wind			12793	40584	83905	141830	239169	283249	366453	408508	472133	513679	547588		20,7	11,0	4,4	2,6	1,5
Solar			371	2172	15307	28018	54353	73156	115047	155244	213167	269202	329948		45,1	13,5	7,8	6,4	4,5
Other renewables (tidal etc.)			0	1	249	575	1724	2863	4265	4635	5691	6811	8804			21,4	9,5	2,9	4,5
Thermal power			407324	433752	483347	514498	479676	448294	425271	399571	408232	405427	381921		1,7	-0,1	-1,2	-0,4	-0,7
of which cogeneration units			76247	85453	98320	120241	121929	125299	132343	142413	150906	151283	152391		2,6	2,2	0,8	1,3	0,1
of which CCS units			0	0	0	0	2711	2711	2711	17421	59014	110509	148782				0,0	36,1	9,7
Solids fired			194165	186620	183619	182252	153772	126961	106137	84672	74814	73155	70193		-0,6	-1,8	-3,6	-3,4	-0,6
Gas fired			129444	166863	218530	240906	229892	222902	218995	211695	220205	211816	187304		5,4	0,5	-0,5	0,1	-1,6
Oil fired			71058	62082	55901	46054	34548	27877	24196	20255	17577	15867	14705		-2,4	-4,7	-3,5	-3,1	-1,8
Biomass-waste fired			12051	17502	24569	44484	60608	69609	74617	81537	94142	103016	108110		7,4	9,4	2,1	2,4	1,4
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	686	727	801	856	945	1325	1413	1495	1574	1610		1,9	1,6	4,5	1,2	0,7
Load factor for net electric capacities (%)			49,1	49,1	43,9	42,4	38,4	36,9	34,2	34,3	33,3	32,5	31,5						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,5	39,9	39,6	39,9	38,8	40,5	42,4	44,3	44,9						
CHP indicator (% of electricity from CHP)			11,4	11,7	14,9	19,0	20,1	21,4	20,4	21,1	19,8	19,0	17,9						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	0,5	0,6	0,7	3,3	10,0	17,2	20,5						
Non fossil fuels in electricity generation (%)			45,8	44,8	47,2	51,0	60,6	65,2	71,4	74,0	76,1	76,8	78,4						
- nuclear			31,6	30,5	27,5	25,7	23,8	21,3	18,6	18,1	16,7	15,1	14,2						
- renewable energy forms and industrial waste			14,2	14,3	19,7	25,3	36,8	43,8	52,9	55,9	59,5	61,7	64,2						
Indicators for renewables (excluding industrial waste) (%) [B]																			
RES in gross final energy demand (%)			7,6	8,6	11,4	14,7	21,3	24,3	27,6	33,3	41,3	49,5	57,3						
RES in transport (%)			0,5	1,4	4,3	6,6	10,9	14,1	19,1	31,0	44,7	55,6	63,7						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**7132,8**	**7455,9**	**7747,0**	**8191,1**	**8478,2**	**8718,8**	**8969,1**	**9155,4**	**1,9**	**1,0**	**1,4**	**0,9**	**0,6**	**0,5**
Public road transport	544,0	504,0	517,6	526,0	545,0	573,7	643,5	703,6	750,2	796,5	837,2	876,4	915,3	-0,5	0,5	1,7	1,5	1,1	0,9
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,0	5288,2	5387,0	5471,6	5714,0	5823,0	5913,0	5993,6	6037,2	2,4	0,9	1,0	0,6	0,3	0,2
Rail	472,5	421,7	447,9	461,0	482,5	525,7	611,8	675,0	735,2	795,9	852,4	923,3	999,7	-0,5	0,7	2,4	1,9	1,5	1,6
Aviation	317,3	351,3	456,9	527,3	576,9	702,8	770,7	852,5	945,0	1014,0	1065,5	1123,4	1149,4	3,7	2,4	2,9	2,1	1,2	0,8
Inland navigation	45,8	44,4	41,7	39,5	40,8	42,5	43,0	44,3	46,7	48,8	50,7	52,4	53,8	-0,9	-0,2	0,5	0,8	0,8	0,6
Travel per person (km per capita)	10376	11127	12248	12756	13038	14048	14510	14961	15754	16284	16764	17303	17767	1,7	0,6	1,1	0,8	0,6	0,6
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2952,5**	**3044,6**	**3126,6**	**3290,4**	**3393,0**	**3492,5**	**3558,0**	**3575,6**	**1,7**	**1,9**	**1,3**	**0,8**	**0,6**	**0,2**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2164,3	2135,3	2124,4	2218,2	2246,4	2271,7	2269,4	2222,9	3,7	2,5	1,0	0,4	0,2	-0,2
Rail	526,3	386,1	403,7	414,1	440,5	489,2	580,8	647,8	698,7	753,4	811,6	864,6	916,6	-2,6	0,9	2,8	1,9	1,5	1,2
Inland navigation	261,6	267,6	273,3	280,2	281,9	299,0	328,5	354,5	373,6	393,2	409,2	424,1	436,0	0,4	0,3	1,5	1,3	0,9	0,6
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	232	215	202	196	187	179	169	158	-0,4	0,7	-0,8	-0,9	-0,9	-1,2
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**369965**	**387155**	**369225**	**346283**	**336253**	**309827**	**274555**	**249888**	**228825**	**1,9**	**0,9**	**0,0**	**-0,9**	**-2,0**	**-1,8**
Public road transport	5197	4732	4914	5039	5182	5315	5450	5424	5067	4778	4027	3552	3413	-0,6	0,5	0,5	-0,7	-2,3	-1,6
Private cars and motorcycles	154395	166321	182974	187736	186407	184712	166635	144181	134057	114545	92322	80824	71252	1,7	0,2	-1,1	-2,2	-3,7	-2,6
Trucks	74969	79037	90951	105104	111606	123126	118018	114862	115960	110166	101954	91543	82474	2,0	2,1	0,6	-0,2	-1,3	-2,1
Rail	9560	9452	9600	9436	9595	10163	11135	11258	10127	9926	9624	9080	8645	0,0	0,0	1,5	-0,9	-0,5	-1,1
Aviation	29038	34112	45395	49703	51709	58141	61911	64123	64281	63437	59545	57841	56124	4,6	1,3	1,8	0,4	-0,8	-0,6
Inland navigation	7110	6963	5555	5386	5466	5699	6076	6435	6761	6975	7083	7048	6917	-2,4	-0,2	1,1	1,1	0,5	-0,2
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	35,4	31,9	28,1	25,4	22,1	18,4	16,3	14,7	0,2	-0,6	-1,7	-2,3	-3,2	-2,2
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,0	45,7	43,1	41,0	39,0	36,1	32,7	29,1	26,2	-0,2	-0,1	-0,7	-1,0	-1,7	-2,2

3. Diversified supply technologies scenario

EU27: Diversified supply technologies scenario														SUMMARY ENERGY BALANCE AND INDICATORS (A)					
ktoe	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Production	936047	950181	941860	900326	833819	806219	782568	741273	710247	736535	769462	779947	759856	0,1	-1,2	-0,6	-1,0	0,8	-0,1
Solids	366477	277810	213423	196277	177950	167093	132831	105139	76032	67826	62855	58584	54278	-5,3	-1,8	-2,9	-5,4	-1,9	-1,5
Oil	129551	171052	173006	134290	104398	73577	46284	35883	31973	23886	14992	6914	2258	2,9	-4,9	-7,8	-3,6	-7,3	-17,2
Natural gas	162447	188965	207559	188677	164866	129039	110512	89498	72741	61103	48339	33115	23552	2,5	-2,3	-3,9	-4,1	-4,0	-6,9
Nuclear	202589	223028	243761	257360	235016	237362	230060	218921	200382	211834	218666	214369	186613	1,9	-0,4	-0,2	-1,4	0,9	-1,6
Renewable energy sources	74984	89326	104111	123722	151589	199149	262880	291833	329118	371886	424609	466965	493156	3,3	3,8	5,7	2,3	2,6	1,5
Hydro	25101	28054	30374	26395	30008	30276	30808	31576	32124	32602	33117	33578	33950	1,9	-0,1	0,3	0,4	0,3	0,2
Biomass & Waste	46473	57201	67982	85129	98966	122954	149764	158637	164137	186903	212324	236947	246870	3,9	3,8	4,2	0,9	2,6	1,5
Wind	67	350	1913	6061	12781	28237	52537	65980	85195	96030	113177	122694	133309	39,8	20,9	15,2	5,0	2,9	1,7
Solar and others	153	274	421	807	3436	9380	18828	23562	32182	39368	48097	54414	58226	10,7	23,3	18,5	5,5	4,1	1,9
Geothermal	3190	3447	3421	5331	6398	8301	10944	12077	15480	16983	17894	19331	20801	0,7	6,5	5,5	3,5	1,5	1,5
Net Imports	756079	738600	826299	986048	969466	1048683	951682	911619	875818	799693	700305	591212	500125	0,9	1,6	-0,2	-0,8	-2,2	-3,3
Solids	81846	79338	98645	126639	102995	116197	85995	68840	43409	34083	27730	17546	22441	1,9	0,4	-1,8	-6,6	-4,4	-2,1
Oil	535645	512185	533039	599851	580687	608084	582484	556160	531957	460462	365970	263491	197447	0,0	0,9	0,0	-0,9	-3,7	-6,0
- Crude oil and Feedstocks	508460	494000	513725	581995	578249	601419	578003	555498	534379	465684	375120	285786	219420	0,1	1,2	0,0	-0,8	-3,5	-5,2
- Oil products	27185	18185	19314	17856	2438	6665	4481	662	-2423	-5222	-9150	-22295	-21973	-3,4	-18,7	6,3			
Natural gas	135121	145288	192531	257366	278100	317390	271194	280220	293381	295569	294978	293594	258514	3,6	3,7	-0,3	0,8	0,1	-1,3
Electricity	3323	1508	1686	971	696	-620	-2139	-2574	-1489	-1854	-1898	-2254	-2610	-6,6	-8,5				
Renewable energy forms	144	279	397	1222	6988	7631	14148	8973	8561	11433	13525	18836	24334	10,7	33,2	7,3	-4,9	4,7	6,0
Gross Inland Consumption	1660159	1662517	1723099	1825989	1753233	1802785	1681336	1600181	1534173	1487363	1423147	1326691	1217114	0,4	0,2	-0,4	-0,9	-0,7	-1,6
Solids	452940	364248	321007	319922	280945	283290	218827	173979	119442	101910	90585	76130	76719	-3,4	-1,3	-2,5	-5,9	-2,7	-1,6
Oil	631058	650858	658727	676859	635033	629544	575853	539331	512591	438574	342295	240510	174832	0,4	-0,4	-1,0	-1,2	-4,0	-6,5
Natural gas	294905	333268	393417	445998	442965	446429	381707	369718	366122	356672	343318	326709	282066	2,9	1,2	-1,5	-0,4	-0,6	-1,9
Nuclear	202589	223028	243761	257360	235016	237362	230060	218921	200382	211834	218666	214369	186613	1,9	-0,4	-0,2	-1,4	0,9	-1,6
Electricity	3323	1508	1686	971	696	-620	-2139	-2574	-1489	-1854	-1898	-2254	-2610	-6,6	-8,5				
Renewable energy forms	75343	89606	104501	124880	158577	206780	277028	300806	337126	380226	430181	471227	499495	3,3	4,3	5,7	2,0	2,5	1,5
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	16,0	15,7	13,0	10,9	7,8	6,9	6,4	5,7	6,3						
Oil	38,0	39,1	38,2	37,1	36,2	34,9	34,2	33,7	33,4	29,5	24,1	18,1	14,4						
Natural gas	17,8	20,0	22,8	24,4	25,3	24,8	22,7	23,1	23,9	24,0	24,1	24,6	23,2						
Nuclear	12,2	13,4	14,1	14,1	13,4	13,2	13,7	13,7	13,1	14,2	15,4	16,2	15,3						
Renewable energy forms	4,5	5,4	6,1	6,8	9,0	11,5	16,5	18,8	22,0	25,6	30,2	35,5	41,0						
Gross Electricity Generation in GWh_e	2562823	2712209	2991720	3274121	3319422	3623036	3677371	3767945	3758199	4096405	4594818	4816170	4912423	1,6	1,0	1,0	0,2	2,0	0,7
Nuclear	794718	881662	944823	997519	911418	921025	896138	863846	794926	842821	872584	867140	793221	1,7	-0,4	-0,2	-1,2	0,9	-0,9
Hydro & wind	292648	330306	375545	378836	514979	713802	1042725	1246880	1552240	1744992	2045510	2241384	2429406	2,5	3,2	7,3	4,1	2,8	1,7
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1893025	1988209	1738508	1657219	1411033	1508593	1676725	1707645	1689795	1,3	1,3	-0,8	-2,1	1,7	0,1
Fuel Inputs for Thermal Power Generation	383492	362334	382613	424208	412181	427685	374835	351638	306109	313991	330702	323691	317428	0,0	0,7	-0,9	-2,0	0,8	-0,4
Solids	263837	230040	223012	229245	209629	213287	154828	115993	66591	60848	61708	63081	70510	-1,7	-0,6	-3,0	-8,1	-0,8	1,3
Oil (including refinery gas)	54404	51463	39294	29780	15656	14040	8336	9901	9869	10226	9542	4516	325	-3,2	-8,8	-6,1	1,7	-0,3	-28,7
Gas	56754	67806	102408	134637	145944	141085	125040	128464	123552	131159	136724	128716	120269	6,1	3,6	-1,5	-0,1	1,0	-1,3
Biomass & Waste	5724	10033	14960	25901	35552	52468	78092	88039	93583	98566	108908	112965	111576	10,1	9,0	8,2	1,8	1,5	0,2
Geothermal heat	2774	2992	2939	4645	5400	6804	8541	9240	12513	13192	13819	14414	14724	0,6	6,3	4,7	3,9	1,0	0,6
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0	0	0	0	24						
Fuel Input in other transformation proc.	839073	814654	827098	842975	793702	793187	744905	708154	678462	607383	509199	400936	328041	-0,1	-0,4	-0,6	-0,9	-2,8	-4,3
Refineries	679426	705954	735244	758152	718083	710257	658909	624834	598425	519944	416361	307164	228035	0,8	-0,2	-0,9	-1,0	-3,6	-5,8
Biofuels and hydrogen production	2	202	610	3129	12208	19510	26830	25839	25763	43488	61535	78040	91677	79,6	34,9	8,2	-0,4	9,1	4,1
District heating	32960	23240	19323	16212	15971	15665	13851	13263	11109	9104	6816	4746	2992	-5,2	-1,9	-1,4	-2,2	-4,8	-7,9
Others	126685	85258	71921	65482	47441	47756	45315	44219	43165	34847	24487	10986	5338	-5,5	-4,1	-0,5	-0,5	-5,5	-14,1
Energy Branch Consumption	82379	88696	88176	96033	91098	90066	83512	77683	72431	69908	70530	67360	63157	0,7	0,3	-0,9	-1,4	-0,3	-1,1
Non-Energy Uses	97931	110541	112495	117477	111507	115321	118126	119713	121498	121009	120142	112694	105832	1,4	-0,1	0,6	0,3	-0,1	-1,3
Final Energy Demand	1068710	1069989	1112989	1173676	1160735	1214824	1145596	1097606	1074761	1025779	953643	878642	803921	0,4	0,4	-0,1	-0,6	-1,2	-1,7
by sector																			
Industry	365650	328513	326949	326308	310880	322813	317708	315743	316063	310591	306942	290646	274547	-1,1	-0,5	0,2	-0,1	-0,3	-1,1
- energy intensive industries	234722	214526	213112	210991	192062	196771	190586	187062	185196	177815	170666	156799	142350	-1,0	-1,0	-0,1	-0,3	-0,8	-1,8
- other industrial sectors	130928	113987	113837	115317	118818	126041	127123	128681	130867	132776	136275	133847	132197	-1,4	0,4	0,7	0,3	0,4	-0,3
Residential	264307	280418	286784	308104	306282	320909	290029	271190	264030	253170	234190	214118	188059	0,8	0,7	-0,5	-0,9	-1,2	-2,2
Tertiary	158484	160442	159866	176859	173607	183950	167348	153008	147122	139991	128571	117233	105749	0,1	0,8	-0,4	-1,3	-1,3	-1,9
Transport	280269	300617	339389	362405	369965	387152	370511	357665	347547	322028	283941	256645	235565	1,9	0,9	0,0	-0,6	-2,0	-1,9
by fuel																			
Solids	125031	84977	61454	54486	47328	44821	39468	33134	27358	19957	14093	6229	2505	-6,9	-2,6	-1,8	-3,6	-6,4	-15,9
Oil	444429	456959	478882	495857	476962	476697	433056	401972	378688	314889	232777	164528	119592	0,7	0,0	-1,0	-1,3	-4,7	-6,4
Gas	227902	245996	265552	283524	268020	274969	227765	210034	212569	192780	165157	137545	99173	1,5	0,1	-1,6	-0,7	-2,5	-5,0
Electricity	184145	193367	216403	237537	242290	265247	270039	277419	279654	296944	315278	316478	311115	1,6	1,1	1,1	0,4	1,2	-0,1
Heat (from CHP and District Heating) [A]	48610	44616	40061	44441	57860	71946	79127	83114	83271	84600	84302	81349	79040	-1,9	3,7	3,2	0,5	0,1	-0,6
Other	38592	44073	50640	57832	68275	81145	96140	91933	93222	116609	142036	172513	192494	2,8	3,0	3,5	-0,3	4,3	3,1
CO_2 Emissions (Mt of CO_2 - sec approach)	4030,6	3800,1	3810,6	3946,6	3689,6	3682,0	3093,4	2773,2	2456,8	2024,6	1481,8	979,3	648,2	-0,6	-0,3	-1,7	-2,3	-4,9	-7,9
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1274,7	1273,7	965,3	818,5	597,7	458,1	270,2	89,7	18,9	-1,2	-0,4	-2,7	-4,7	-7,6	-23,3
Energy Branch	152,2	171,0	170,2	181,6	157,2	145,6	127,6	113,4	102,9	79,2	61,3	44,6	26,2	1,1	-0,8	-2,1	-2,1	-5,1	-8,1
Industry	781,4	678,1	623,0	581,9	497,5	479,6	435,0	414,2	408,2	359,8	309,5	233,2	170,4	-2,2	-2,2	-1,3	-0,6	-2,7	-5,8
Residential	499,4	481,6	466,2	486,7	466,4	466,2	383,9	326,4	311,5	262,3	194,0	135,2	74,6	-0,7	0,0	-1,9	-2,1	-4,6	-9,1
Tertiary	300,5	275,3	242,0	262,2	245,6	239,3	188,8	164,1	156,5	135,6	99,9	67,8	39,4	-2,1	0,1	-2,6	-1,9	-4,4	-8,9
Transport	812,7	872,9	988,5	1053,1	1048,2	1077,6	992,8	936,7	880,0	729,6	546,9	408,9	318,6	2,0	0,6	-0,5	-1,2	-4,6	-5,3
CO_2 Emissions Index (1990=100)	100,0	94,3	94,5	97,9	91,5	91,3	76,7	68,8	61,0	50,2	36,8	24,3	16,1						
CO_2 Emissions (Mt of CO_2 - ref approach)	4172,0	3950,7	3922,7	4087,6	3756,9	3749,7	3161,4	2840,1	2525,4	2087,6	1547,5	1068,6	753,3	-0,6	-0,4	-1,7	-2,2	-4,8	-6,9

EU27: Diversified supply technologies scenario													SUMMARY ENERGY BALANCE AND INDICATORS (B)						
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12750,3	14164,0	15503,7	16824,7	18157,1	19527,9	21002,9	22560,0	2,2	1,2	2,2	1,7	1,5	1,5
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	154,0	141,4	118,7	103,2	91,2	81,9	72,9	63,2	54,0	-1,8	-1,0	-2,6	-2,6	-2,2	-3,0
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,51	3,55	3,27	3,09	2,95	2,86	2,74	2,56	2,36	0,1	-0,2	-0,7	-1,0	-0,8	-1,5
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6647	7136	7157	7277	7228	7868	8834	9291	9533	1,3	0,7	0,7	0,1	2,0	0,8
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,10	2,04	1,84	1,73	1,60	1,36	1,04	0,74	0,53	-0,9	-0,5	-1,3	-1,4	-4,2	-6,5
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,39	7,25	6,02	5,36	4,73	3,89	2,85	1,89	1,26	-0,8	-0,7	-2,0	-2,4	-4,9	-7,9
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	324,1	288,8	218,4	178,9	146,0	111,5	75,9	46,6	28,7	-2,7	-1,5	-3,9	-3,9	-6,3	-9,3
Import Dependency %	44,6	43,5	46,8	52,5	53,8	56,5	54,9	55,2	55,2	52,1	47,6	43,1	39,7						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	89,9	84,5	75,4	68,9	64,1	58,6	54,1	47,9	42,4	-2,6	-1,1	-1,7	-1,6	-1,7	-2,4
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,2	89,6	73,3	63,3	57,2	50,3	43,4	36,6	30,1	-1,3	-0,4	-2,7	-2,4	-2,7	-3,6
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	93,9	88,0	71,8	59,7	52,7	46,3	39,4	33,3	27,8	-2,3	-0,6	-2,6	-3,1	-2,9	-3,4
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	90,4	77,9	68,7	61,5	52,8	43,3	36,4	31,1	-0,2	-0,3	-2,1	-2,3	-3,5	-3,3
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,31	0,27	0,20	0,17	0,12	0,09	0,05	0,02	0,00	-2,1	-1,9	-4,1	-4,9	-9,0	
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,95	1,86	1,75	1,68	1,63	1,45	1,21	0,96	0,75	-0,7	-0,7	-1,1	-0,7	-3,0	-4,6
Industry	2,14	2,06	1,91	1,78	1,60	1,49	1,37	1,31	1,29	1,16	1,01	0,80	0,62	-1,1	-1,7	-1,5	-0,6	-2,4	-4,7
Residential	1,89	1,72	1,63	1,58	1,52	1,45	1,32	1,20	1,18	1,04	0,83	0,63	0,40	-1,5	-0,7	-1,4	-1,1	-3,5	-7,1
Tertiary	1,90	1,72	1,51	1,48	1,41	1,30	1,13	1,07	1,06	0,97	0,78	0,58	0,37	-2,2	-0,7	-2,2	-0,6	-3,1	-7,1
Transport	2,90	2,90	2,91	2,91	2,83	2,78	2,68	2,62	2,53	2,27	1,93	1,59	1,35	0,0	-0,3	-0,6	-0,6	-2,7	-3,5
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654168**	**715466**	**821492**	**926838**	**1030076**	**1077932**	**1192511**	**1274724**	**1452239**	**1565336**	**1620951**		**2,3**	**2,3**	**1,5**	**2,0**	**1,1**
Nuclear energy			133966	134452	131393	125743	124707	106684	104841	106207	109310	114100	101712		-0,2	-0,5	-1,7	0,4	-0,7
Renewable energy			112878	147262	206776	283873	420168	503915	642175	733432	878759	980140	1080701		6,2	7,3	4,3	3,2	2,1
Hydro (pumping excluded)			99714	104505	107315	111550	114915	116945	118918	121015	122055	123611	125633		0,7	0,7	0,3	0,3	0,3
Wind			12793	40584	83905	143729	247338	302919	386165	433350	505776	546147	594652		20,7	11,4	4,6	2,7	1,6
Solar			371	2172	15307	28018	56183	81070	132827	173250	244150	302357	350540		45,1	13,9	9,0	6,3	3,7
Other renewables (tidal etc.)			0	1	249	575	1732	2981	4265	5818	6778	8026	9876			21,4	9,4	4,7	3,8
Thermal power			407324	433752	483323	517222	485201	467333	445495	435085	464169	471095	438539		1,7	0,0	-0,9	0,4	-0,6
of which cogeneration units			76247	85453	98242	119491	124538	132761	141487	153435	157838	162549	161436		2,6	2,4	1,3	1,1	0,2
of which CCS units			0	0	0	0	2711	2711	3436	31909	94816	160119	192600				2,4	39,3	7,3
Solids fired			194165	186620	183617	182688	154351	128492	107941	96189	95149	94999	93591		-0,6	-1,7	-3,5	-1,3	-0,2
Gas fired			129444	166863	218508	242854	232921	233881	229826	226031	246728	249817	218321		5,4	0,6	-0,1	0,7	-1,2
Oil fired			71058	62082	55901	46070	34961	32427	29356	27364	24397	19764	18894		-2,4	-4,6	-1,7	-1,8	-2,5
Biomass-waste fired			12051	17502	24570	44703	61830	71302	76706	83745	96056	104597	105774		7,4	9,7	2,2	2,3	1,0
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	686	727	908	1138	1231	1665	1755	1839	1918	1959		1,9	4,6	3,9	1,0	0,6
Load factor for net electric capacities (%)			49,1	49,1	43,9	42,6	39,0	38,4	34,8	35,2	34,3	33,1	32,5						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,5	40,0	39,9	40,5	39,6	41,3	43,6	45,4	45,8						
CHP indicator (% of electricity from CHP)			11,4	11,7	14,9	19,0	20,3	21,1	20,7	20,2	18,4	18,2	16,9						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	0,6	0,6	0,8	6,1	14,9	21,8	24,2						
Non fossil fuels in electricity generation (%)			45,8	44,8	47,2	50,7	60,9	65,3	72,4	73,0	73,4	74,5	75,2						
- nuclear			31,6	30,5	27,5	25,4	24,4	22,9	21,2	20,6	19,0	18,0	16,1						
- renewable energy forms and industrial waste			14,2	14,3	19,7	25,3	36,6	42,4	51,2	52,4	54,4	56,5	59,1						
Indicators for renewables (excluding industrial waste) (%) (a)																			
RES in gross final energy demand (%)			7,6	8,6	11,4	14,8	21,3	24,2	27,7	32,6	39,8	47,4	54,6						
RES in transport (%)			0,5	1,4	4,3	6,6	10,9	13,8	18,6	29,8	43,0	53,7	61,9						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**7132,6**	**7479,8**	**7914,0**	**8358,8**	**8672,0**	**8919,9**	**9164,8**	**9355,2**	**1,9**	**1,0**	**1,4**	**1,1**	**0,7**	**0,5**
Public road transport	544,0	504,0	517,6	526,0	545,0	573,7	639,6	675,1	721,4	766,9	807,1	846,7	886,3	-0,5	0,5	1,6	1,2	1,1	0,9
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,0	5288,2	5414,1	5648,7	5889,0	6019,0	6113,2	6186,1	6231,5	2,4	0,9	1,1	0,8	0,4	0,2
Rail	472,5	421,7	447,9	461,0	482,5	525,5	607,2	645,5	704,3	764,1	819,8	890,5	966,4	-0,5	0,7	2,3	1,5	1,5	1,7
Aviation	317,3	351,3	456,9	527,3	576,9	702,8	775,7	899,7	996,7	1072,4	1128,5	1188,4	1216,3	3,7	2,4	3,0	2,5	1,2	0,8
Inland navigation	45,8	44,4	41,7	39,5	40,8	42,5	43,1	45,0	47,4	49,6	51,5	53,1	54,6	-0,9	-0,2	0,6	1,0	0,8	0,6
Travel per person (km per capita)	10376	11127	12248	12756	13038	14048	14557	15283	16076	16656	17150	17680	18155	1,7	0,6	1,1	1,0	0,6	0,6
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2952,5**	**3058,1**	**3212,4**	**3375,0**	**3493,1**	**3597,3**	**3655,5**	**3666,4**	**1,7**	**1,9**	**1,4**	**1,0**	**0,6**	**0,2**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2164,3	2155,1	2255,0	2349,0	2393,5	2424,7	2414,9	2362,3	3,7	2,5	1,1	0,9	0,3	-0,3
Rail	526,3	386,1	403,7	414,1	440,5	489,1	575,1	608,3	658,0	711,9	769,0	822,1	874,1	-2,6	0,9	2,7	1,4	1,6	1,3
Inland navigation	261,6	267,6	273,3	280,2	281,9	299,0	327,8	349,1	368,0	387,8	403,6	418,4	430,0	0,4	0,3	1,5	1,2	0,9	0,6
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	232	216	207	201	192	184	174	163	-0,4	0,7	-0,8	-0,7	-0,8	-1,2
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**369965**	**387152**	**370511**	**357665**	**347547**	**322028**	**283941**	**256645**	**235565**	**1,9**	**0,9**	**0,0**	**-0,6**	**-2,0**	**-1,9**
Public road transport	5197	4732	4914	5039	5182	5315	5423	5237	4922	4644	3847	3429	3315	-0,6	0,5	0,5	-1,0	-2,4	-1,5
Private cars and motorcycles	154395	166321	182974	187736	186407	184711	167399	148661	139252	120689	95654	83490	73071	1,7	0,2	-1,1	-1,8	-3,7	-2,7
Trucks	74969	79037	90951	105104	111606	123126	119059	121497	122053	116030	107072	95127	86415	2,0	2,1	0,6	0,2	-1,3	-2,1
Rail	9560	9452	9600	9436	9595	10161	11030	10601	9637	9494	9225	8719	8326	0,0	0,0	1,4	-1,3	-0,4	-1,0
Aviation	29038	34112	45395	49703	51709	58141	61530	65280	64973	64251	61125	58944	57623	4,6	1,3	1,8	0,5	-0,6	-0,6
Inland navigation	7110	6963	5555	5386	5466	5699	6070	6387	6710	6919	7018	6936	6816	-2,4	-0,2	1,1	1,0	0,5	-0,3
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	35,4	31,9	28,2	25,5	22,4	18,5	16,4	14,8	0,2	-0,6	-1,7	-2,2	-3,2	-2,2
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,0	45,7	43,2	41,8	39,7	36,6	33,1	29,1	26,6	-0,2	-0,1	-0,6	-0,8	-1,8	-2,2

4. High RES scenario

EU27: High RES scenario														SUMMARY ENERGY BALANCE AND INDICATORS (A)					
ktoe	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**'90-'00**	**'00-'10**	**'10-'20**	**'20-'30**	**'30-'40**	**'40-'50**
														Annual % Change					
Production	**936047**	**950181**	**941860**	**900326**	**833310**	**806698**	**779610**	**742056**	**698518**	**699081**	**731599**	**752101**	**764124**	**0,1**	**-1,2**	**-0,7**	**-1,1**	**0,5**	**0,4**
Solids	366477	277810	213423	196277	177924	167143	130847	105741	70120	50626	42866	34971	29452	-5,3	-1,8	-3,0	-6,0	-4,8	-3,7
Oil	129551	171052	173006	134290	104398	73819	46224	35904	31670	23560	14980	7066	2278	2,9	-4,9	-7,8	-3,7	-7,2	-17,2
Natural gas	162447	188965	207559	188677	164866	129037	110518	89489	71627	58053	44334	29044	19735	2,5	-2,3	-3,9	-4,2	-4,7	-7,8
Nuclear	202589	223028	243761	257360	235016	237344	229652	213206	145795	112636	85647	64628	43640	1,9	-0,4	-0,2	-4,4	-5,2	-6,5
Renewable energy sources	74984	89326	104111	123722	151107	199354	262370	297715	379306	454205	543773	616393	669019	3,3	3,8	5,7	3,8	3,7	2,1
Hydro	25101	28054	30374	26395	30008	30294	30817	31604	32220	32722	33245	33693	34059	1,9	-0,1	0,3	0,4	0,3	0,2
Biomass & Waste	46473	57201	67982	85129	98472	122897	149005	159999	180886	218149	253415	282753	294621	3,9	3,8	4,2	2,0	3,4	1,5
Wind	67	350	1913	6061	12781	28465	52714	67465	103030	125049	161406	189752	215507	39,8	20,9	15,2	6,9	4,6	2,9
Solar and others	153	274	421	807	3446	9395	19017	26413	40371	52058	67572	79864	90649	10,7	23,4	18,6	7,8	5,3	3,0
Geothermal	3190	3447	3421	5331	6400	8305	10817	12234	22800	26227	28134	30331	34182	0,7	6,5	5,4	7,7	2,1	2,0
Net Imports	**756079**	**738600**	**826299**	**986048**	**969129**	**1046554**	**952439**	**911227**	**863234**	**767139**	**631727**	**510481**	**413127**	**0,9**	**1,6**	**-0,2**	**-1,0**	**-3,1**	**-4,2**
Solids	81846	79338	98645	126639	102268	112548	86128	69892	38524	19365	7407	-6329	-6046	1,9	0,4	-1,7	-7,7	-15,2	
Oil	535645	512185	533039	599851	580795	609089	582627	557236	533764	460454	364573	263832	198402	0,0	0,9	0,0	-0,9	-3,7	-5,9
- Crude oil and Feedstocks	508460	494000	513725	581995	578276	603822	577997	556269	534989	464675	373779	285995	221344	0,1	1,2	0,0	-0,8	-3,5	-5,1
- Oil products	27185	18185	19314	17856	2519	5267	4630	967	-1225	-4221	-9206	-22163	-22942	-3,4	-18,4	6,3			
Natural gas	135121	145288	192531	257366	278450	317916	271631	276670	282045	273453	241524	227188	190699	3,6	3,8	-0,2	0,4	-1,5	-2,3
Electricity	3323	1508	1686	971	696	-634	-2118	-1959	558	1723	3146	4397	4829	-6,6	-8,5			18,9	4,4
Renewable energy forms	144	279	397	1222	6921	7636	14171	9388	8342	12143	15077	21393	25243	10,7	33,1	7,4	-5,2	6,1	5,3
Gross Inland Consumption	**1660159**	**1662517**	**1723099**	**1825989**	**1752388**	**1801136**	**1679135**	**1600572**	**1509860**	**1417185**	**1316560**	**1217955**	**1134336**	**0,4**	**0,2**	**-0,4**	**-1,1**	**-1,4**	**-1,5**
Solids	452940	364248	321007	319922	280191	279691	216975	175633	108644	69991	50272	28642	23406	-3,4	-1,4	-2,5	-6,7	-7,4	-7,4
Oil	631058	650858	658727	676859	635141	630791	575936	540429	514095	438052	340749	240880	175825	0,4	-0,4	-1,0	-1,1	-4,0	-6,4
Natural gas	294905	333268	393417	445998	443315	446953	382149	366159	353672	331506	285858	256232	210434	2,9	1,2	-1,5	-0,8	-2,1	-3,0
Nuclear	202589	223028	243761	257360	235016	237344	229652	213206	145795	112636	85647	64628	43640	1,9	-0,4	-0,2	-4,4	-5,2	-6,5
Electricity	3323	1508	1686	971	696	-634	-2118	-1959	558	1723	3146	4397	4829	-6,6	-8,5			18,9	4,4
Renewable energy forms	75343	89606	104501	124880	158028	206990	276541	307103	387095	463277	550887	623177	676202	3,3	4,2	5,8	3,4	3,6	2,1
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	16,0	15,5	12,9	11,0	7,2	4,9	3,8	2,4	2,1						
Oil	38,0	39,1	38,2	37,1	36,2	35,0	34,3	33,8	34,0	30,9	25,9	19,8	15,5						
Natural gas	17,8	20,0	22,8	24,4	25,3	24,8	22,8	22,9	23,4	23,4	21,7	21,0	18,6						
Nuclear	12,2	13,4	14,1	14,1	13,4	13,2	13,7	13,3	9,7	7,9	6,5	5,3	3,8						
Renewable energy forms	4,5	5,4	6,1	6,8	9,0	11,5	16,5	19,2	25,6	32,7	41,8	51,2	59,6						
Gross Electricity Generation in GWh_e	**2562823**	**2712209**	**2991720**	**3274121**	**3310017**	**3609375**	**3665380**	**3751472**	**3666305**	**3879733**	**4357597**	**4726244**	**5140565**	**1,6**	**1,0**	**1,0**	**0,0**	**1,7**	**1,7**
Nuclear	794718	881662	944823	997519	911418	920951	894470	840519	578404	449157	344218	260161	179105	1,7	-0,4	-0,2	-4,3	-5,1	-6,3
Hydro & wind	292648	330306	375545	378836	514979	716559	1046829	1280628	1838420	2222236	2819421	3298070	3744893	2,5	3,2	7,4	5,8	4,4	2,9
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1883620	1971864	1724081	1630325	1249481	1208340	1193958	1168013	1216567	1,3	1,2	-0,9	-3,2	-0,5	0,2
Fuel Inputs for Thermal Power Generation	**383492**	**362334**	**382613**	**424208**	**410954**	**424609**	**371495**	**346950**	**280705**	**264227**	**256594**	**249960**	**264725**	**0,0**	**0,7**	**-1,0**	**-2,8**	**-0,9**	**0,3**
Solids	263837	230040	223012	229245	208905	209783	153229	116717	53950	29831	22172	15880	17556	-1,7	-0,7	-3,1	-9,9	-8,5	-2,3
Oil (including refinery gas)	54404	51463	39294	29780	15595	14589	8560	10199	9028	8466	6629	2096	246	-3,2	-8,8	-5,8	0,5	-3,0	-28,0
Gas	56754	67806	102408	134637	145869	141081	124787	126024	110577	110044	85265	66166	55752	6,1	3,6	-1,5	-1,2	-2,6	-4,2
Biomass & Waste	5724	10033	14960	25901	35185	52352	76511	84921	88926	94230	107154	111032	109233	10,1	8,9	8,1	1,5	1,9	0,2
Geothermal heat	2774	2992	2939	4645	5400	6804	8409	9089	18156	20713	22294	23895	26799	0,6	6,3	4,5	8,0	2,1	1,9
Hydrogen - Methanol	0	0	0	0	0	0	0	0	69	942	13079	30891	55138					69,0	15,5
Fuel Input in other transformation proc.	**839073**	**814654**	**827098**	**842975**	**793843**	**795868**	**744588**	**709740**	**683212**	**609457**	**525856**	**442356**	**399684**	**-0,1**	**-0,4**	**-0,6**	**-0,9**	**-2,6**	**-2,7**
Refineries	679426	705954	735244	758152	718104	712903	658842	625630	598726	518600	415000	307676	230223	0,8	-0,2	-0,9	-1,0	-3,6	-5,7
Biofuels and hydrogen production	2	202	610	3129	12208	19510	26833	25850	25967	44429	77991	116325	158393	79,6	34,9	8,2	-0,3	11,6	7,3
District heating	32960	23240	19323	16212	15983	15699	13874	13522	13912	11437	8920	6722	5813	-5,2	-1,9	-1,4	0,0	-4,3	-4,2
Others	126685	85258	71921	65482	47547	47757	45039	44738	44607	34990	23945	11634	5255	-5,5	-4,1	-0,5	-0,1	-6,0	-14,1
Energy Branch Consumption	**82379**	**88696**	**88176**	**96033**	**90926**	**90041**	**83106**	**77580**	**70485**	**63523**	**56656**	**52976**	**48370**	**0,7**	**0,3**	**-0,9**	**-1,6**	**-2,2**	**-1,6**
Non-Energy Uses	**97931**	**110541**	**112495**	**117477**	**111488**	**115324**	**118124**	**119728**	**121483**	**120976**	**120110**	**112142**	**105116**	**1,4**	**-0,1**	**0,6**	**0,3**	**-0,1**	**-1,3**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173676**	**1160711**	**1214573**	**1145345**	**1103544**	**1093422**	**1039229**	**965315**	**885616**	**804231**	**0,4**	**0,4**	**-0,1**	**-0,5**	**-1,2**	**-1,8**
by sector																			
Industry	365650	328513	326949	326308	310794	322842	317478	316730	319583	314659	311272	291614	275822	-1,1	-0,5	0,2	0,1	-0,3	-1,2
- energy intensive industries	234722	214526	213112	210991	192050	196819	190503	188016	187697	180244	173169	157044	142999	-1,0	-1,0	-0,1	-0,1	-0,8	-1,9
- other industrial sectors	130928	113987	113837	115317	118743	126023	126975	128714	131887	134414	138104	134570	132823	-1,4	0,4	0,7	0,4	0,5	-0,4
Residential	264307	280418	286784	308104	306349	320875	289859	273993	273054	260550	240796	220031	190190	0,8	0,7	-0,6	-0,6	-1,2	-2,3
Tertiary	158484	160442	159866	176859	173601	183698	167475	154457	151363	140799	126815	114332	100614	0,1	0,8	-0,4	-1,0	-1,8	-2,3
Transport	280269	300617	339389	362405	369967	387158	370533	358363	349421	323222	286432	259639	237605	1,9	0,9	0,0	-0,6	-2,0	-1,9
by fuel																			
Solids	125031	84977	61454	54486	47220	44757	39481	33969	29050	19765	14092	5914	2458	-6,9	-2,6	-1,8	-3,0	-7,0	-16,0
Oil	444429	456959	478882	495857	477402	476889	433240	403337	382481	317430	235116	166879	120383	0,7	0,0	-1,0	-1,2	-4,7	-6,5
Gas	227902	245996	265552	283524	268457	275889	227971	209061	212137	193706	165069	137402	95510	1,5	0,1	-1,6	-0,7	-2,5	-5,3
Electricity	184145	193367	216403	237537	241593	264268	269375	277243	277332	290261	301824	296091	290419	1,6	1,1	1,1	0,3	0,8	-0,4
Heat (from CHP and District Heating) [(A)]	48610	44616	40061	44441	57920	71519	78393	82568	78039	71951	69538	61492	53924	-1,9	3,8	3,1	0,0	-1,1	-2,5
Other	38592	44073	50640	57832	68119	81250	96886	97365	114383	146118	179676	217838	241538	2,8	3,0	3,6	1,7	4,6	3,0
CO_2 Emissions (Mt of CO_2 - sec approach)	**4030,6**	**3800,1**	**3810,6**	**3946,6**	**3687,8**	**3672,9**	**3087,1**	**2776,2**	**2394,9**	**1964,4**	**1454,9**	**986,9**	**670,0**	**-0,6**	**-0,3**	**-1,8**	**-2,5**	**-4,9**	**-7,5**
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1271,6	1261,5	957,9	817,6	523,3	403,4	250,3	103,5	52,5	-1,2	-0,4	-2,8	-5,9	-7,1	-14,5
Energy Branch	152,2	171,0	170,2	181,6	156,5	146,2	127,7	112,0	97,6	65,1	48,0	33,0	21,1	1,1	-0,8	-2,0	-2,7	-6,8	-7,9
Industry	781,4	678,1	623,0	581,9	498,3	480,6	434,7	412,7	407,6	363,6	314,0	238,3	165,7	-2,2	-2,2	-1,4	-0,6	-2,6	-6,2
Residential	499,4	481,6	466,2	486,7	466,9	466,9	384,3	329,2	318,5	260,1	186,8	125,4	66,6	-0,7	0,0	-1,9	-1,9	-5,2	-9,8
Tertiary	300,5	275,3	242,0	262,2	246,3	240,1	189,7	166,1	162,3	138,4	102,2	70,7	41,0	-2,1	0,2	-2,6	-1,5	-4,5	-8,7
Transport	812,7	872,9	988,5	1053,1	1048,2	1077,6	992,9	938,6	885,6	733,8	553,5	416,0	323,1	2,0	0,6	-0,5	-1,1	-4,6	-5,2
CO_2 Emissions Index (1990=100)	**100,0**	**94,3**	**94,5**	**97,9**	**91,5**	**91,1**	**76,6**	**68,9**	**59,4**	**48,7**	**36,1**	**24,5**	**16,6**						
CO_2 Emissions (Mt of CO_2 - ref approach)	**4172,0**	**3950,7**	**3922,7**	**4087,6**	**3755,2**	**3740,5**	**3154,9**	**2843,0**	**2463,7**	**2028,4**	**1522,0**	**1075,6**	**775,5**	**-0,6**	**-0,4**	**-1,7**	**-2,4**	**-4,7**	**-6,5**

EU27: High RES scenario														SUMMARY ENERGY BALANCE AND INDICATORS (B)					
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12750,3	14164,0	15503,7	16824,7	18157,1	19527,9	21002,9	22560,0	2,2	1,2	2,2	1,7	1,5	1,5
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	153,9	141,3	118,5	103,2	89,7	78,1	67,4	58,0	50,3	-1,8	-1,0	-2,6	-2,7	-2,8	-2,9
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,51	3,55	3,27	3,09	2,90	2,72	2,53	2,35	2,20	0,1	-0,2	-0,7	-1,2	-1,4	-1,4
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6628	7109	7133	7245	7051	7452	8378	9118	9976	1,3	0,6	0,7	-0,1	1,7	1,8
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,10	2,04	1,84	1,73	1,59	1,39	1,11	0,81	0,59	-0,9	-0,5	-1,3	-1,5	-3,5	-6,1
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,38	7,23	6,01	5,36	4,61	3,77	2,80	1,90	1,30	-0,8	-0,7	-2,0	-2,6	-4,9	-7,4
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	323,9	288,1	218,0	179,1	142,3	108,2	74,5	47,0	29,7	-2,7	-1,5	-3,9	-4,2	-6,3	-8,8
Import Dependency %	44,6	43,5	46,8	52,5	53,8	56,5	55,0	55,1	55,3	52,3	46,3	40,4	35,1						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	89,8	84,6	75,3	69,1	64,8	59,4	54,9	48,1	42,6	-2,6	-1,1	-1,7	-1,5	-1,6	-2,5
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,3	89,6	73,3	63,9	59,1	51,8	44,6	37,6	30,5	-1,3	-0,4	-2,7	-2,1	-2,8	-3,7
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	93,9	87,9	71,9	60,3	54,2	46,6	38,9	32,5	26,5	-2,3	-0,6	-2,6	-2,8	-3,3	-3,8
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	90,4	77,9	68,8	61,8	53,0	43,7	36,8	31,4	-0,2	-0,3	-2,1	-2,3	-3,4	-3,3
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,31	0,27	0,20	0,17	0,11	0,08	0,05	0,02	0,01	-2,1	-2,0	-4,2	-5,8	-8,1	
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,95	1,87	1,75	1,67	1,62	1,44	1,20	0,96	0,74	-0,7	-0,7	-1,1	-0,7	-3,0	-4,7
Industry	2,14	2,06	1,91	1,78	1,60	1,49	1,37	1,30	1,28	1,16	1,01	0,82	0,60	-1,1	-1,7	-1,6	-0,7	-2,3	-5,0
Residential	1,89	1,72	1,63	1,58	1,52	1,45	1,33	1,20	1,17	1,00	0,78	0,57	0,35	-1,5	-0,6	-1,4	-1,3	-4,0	-7,6
Tertiary	1,90	1,72	1,51	1,48	1,42	1,31	1,13	1,08	1,07	0,98	0,81	0,62	0,41	-2,2	-0,6	-2,2	-0,5	-2,8	-6,6
Transport	2,90	2,90	2,91	2,91	2,83	2,78	2,68	2,62	2,53	2,27	1,93	1,60	1,36	0,0	-0,3	-0,6	-0,6	-2,7	-3,5
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654168**	**715466**	**821393**	**925364**	**1028870**	**1093152**	**1323971**	**1473174**	**1763357**	**2002770**	**2219028**		**2,3**	**2,3**	**2,6**	**2,9**	**2,3**
Nuclear energy			133966	134452	131393	125743	124752	106542	89509	74531	70208	59974	40649		-0,2	-0,5	-3,3	-2,4	-5,3
Renewable energy			112878	147262	206776	284863	421571	520864	790367	975140	1266151	1510674	1748963		6,2	7,4	6,5	4,8	3,3
Hydro (pumping excluded)			99714	104505	107315	111624	114963	117041	120084	124646	127086	129206	131439		0,7	0,7	0,4	0,6	0,3
Wind			12793	40584	83905	144765	247477	308743	469770	567394	734513	865683	984455		20,7	11,4	6,6	4,6	3,0
Solar			371	2172	15307	27898	57398	92099	195255	272546	385411	491250	602883		45,1	14,1	13,0	7,0	4,6
Other renewables (tidal etc.)			0	1	249	575	1732	2981	5259	10554	19140	24534	30187			21,4	11,7	13,8	4,7
Thermal power			407324	433752	483224	514758	482548	465746	444095	423503	426999	432122	429416		1,7	0,0	-0,8	-0,4	0,1
of which cogeneration units			76247	85453	97871	118960	124171	132317	135857	154830	170519	176464	178477		2,5	2,4	0,9	2,3	0,5
of which CCS units			0	0	0	0	2711	2711	2711	6268	22077	42460	52528				0,0	23,3	9,1
Solids fired			194165	186620	183457	182723	154491	129046	107532	83960	73806	67977	62189		-0,6	-1,7	-3,6	-3,7	-1,7
Gas fired			129444	166863	218569	241148	231203	231452	227152	215553	204223	193967	181585		5,4	0,6	-0,2	-1,1	-1,2
Oil fired			71058	62082	55901	45785	34998	33937	29321	24824	20949	20026	18956		-2,4	-4,6	-1,8	-3,3	-1,0
Biomass-waste fired			12051	17502	24569	44194	60735	70101	77673	96413	125058	146976	163125		7,4	9,5	2,5	4,9	2,7
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	686	727	908	1121	1211	2418	2754	2964	3176	3562		1,9	4,4	8,0	2,1	1,9
Load factor for net electric capacities (%)			49,1	49,1	43,8	42,5	39,0	37,7	30,7	29,3	27,0	25,5	24,8						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,4	39,9	39,9	40,4	38,3	39,3	40,0	40,2	39,5						
CHP indicator (% of electricity from CHP)			11,4	11,7	14,8	18,8	20,2	21,1	18,5	17,5	15,2	13,0	10,5						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	0,6	0,6	0,6	0,9	3,3	6,0	6,9						
Non fossil fuels in electricity generation (%)			45,8	44,8	47,3	50,9	61,0	65,6	75,6	79,2	84,8	88,5	90,0						
- nuclear			31,6	30,5	27,5	25,5	24,4	22,4	15,8	11,6	8,0	5,7	3,6						
- renewable energy forms and industrial waste			14,2	14,3	19,8	25,4	36,6	43,2	59,8	67,6	76,8	82,9	86,4						
Indicators for renewables (excluding industrial waste) (%) [(B)]																			
RES in gross final energy demand (%)			7,6	8,6	11,4	14,8	21,3	24,6	31,2	39,1	50,6	63,0	75,2						
RES in transport (%)			0,5	1,4	4,3	6,6	10,9	13,9	20,0	33,3	50,2	63,2	73,5						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**7133,0**	**7480,3**	**7921,8**	**8379,5**	**8681,7**	**8912,2**	**9140,9**	**9287,2**	**1,9**	**1,0**	**1,4**	**1,1**	**0,6**	**0,4**
Public road transport	544,0	504,0	517,6	526,0	545,0	573,7	639,6	675,1	721,1	766,5	806,9	846,2	887,8	-0,5	0,5	1,6	1,2	1,1	1,0
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,0	5288,2	5414,1	5655,3	5908,7	6030,5	6111,5	6174,0	6179,1	2,4	0,9	1,1	0,9	0,3	0,1
Rail	472,5	421,7	447,9	461,0	482,5	525,9	607,7	646,0	703,3	761,5	813,5	878,4	953,4	-0,5	0,7	2,3	1,5	1,5	1,6
Aviation	317,3	351,3	456,9	527,3	576,9	702,8	775,7	900,3	999,1	1073,6	1128,9	1189,1	1212,4	3,7	2,4	3,0	2,6	1,2	0,7
Inland navigation	45,8	44,4	41,7	39,5	40,8	42,5	43,1	45,0	47,4	49,6	51,5	53,2	54,5	-0,9	-0,2	0,6	1,0	0,8	0,6
Travel per person (km per capita)	10376	11127	12248	12756	13038	14049	14558	15299	16116	16675	17135	17634	18023	1,7	0,6	1,1	1,0	0,6	0,5
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2952,6**	**3058,2**	**3216,8**	**3387,8**	**3499,1**	**3597,1**	**3654,0**	**3646,6**	**1,7**	**1,9**	**1,4**	**1,0**	**0,6**	**0,1**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2164,3	2155,1	2259,0	2362,1	2400,8	2427,4	2419,1	2347,9	3,7	2,5	1,1	0,9	0,3	-0,3
Rail	526,3	386,1	403,7	414,1	440,5	489,3	575,3	608,5	657,5	710,6	766,1	816,4	868,7	-2,6	0,9	2,7	1,3	1,5	1,3
Inland navigation	261,6	267,6	273,3	280,2	281,9	299,0	327,8	349,2	368,2	387,8	403,6	418,4	430,0	0,4	0,3	1,5	1,2	0,9	0,6
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	232	216	207	201	193	184	174	162	-0,4	0,7	-0,8	-0,7	-0,9	-1,3
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**369967**	**387158**	**370533**	**358363**	**349421**	**323222**	**286432**	**259639**	**237605**	**1,9**	**0,9**	**0,0**	**-0,6**	**-2,0**	**-1,9**
Public road transport	5197	4732	4914	5039	5182	5315	5423	5239	4928	4673	3910	3474	3317	-0,6	0,5	0,5	-1,0	-2,3	-1,6
Private cars and motorcycles	154395	166321	182974	187736	186407	184712	167417	148591	139470	120494	97075	85366	75653	1,7	0,2	-1,1	-1,8	-3,6	-2,5
Trucks	74969	79037	90951	105104	111606	123126	119059	121710	122731	116740	107691	95806	86075	2,0	2,1	0,6	0,3	-1,3	-2,2
Rail	9560	9452	9600	9436	9597	10166	11035	10609	9631	9491	9275	8779	8356	0,0	0,0	1,4	-1,4	-0,4	-1,0
Aviation	29038	34112	45395	49703	51709	58141	61530	65826	65945	64896	61450	59255	57377	4,6	1,3	1,8	0,7	-0,7	-0,7
Inland navigation	7110	6963	5555	5386	5466	5699	6070	6389	6715	6929	7030	6958	6827	-2,4	-0,2	1,1	1,0	0,5	-0,3
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	35,4	31,9	28,3	25,6	22,4	18,7	16,7	15,1	0,2	-0,6	-1,7	-2,2	-3,1	-2,1
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,1	45,7	43,2	41,8	39,8	36,8	33,3	29,4	26,6	-0,2	-0,1	-0,6	-0,8	-1,8	-2,2

5. Delayed CCS scenario

EU27: Delayed CCS scenario														SUMMARY ENERGY BALANCE AND INDICATORS (A)					
ktoe	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**'90-'00**	**'00-'10**	**'10-'20**	**'20-'30**	**'30-'40**	**'40-'50**
														Annual % Change					
Production	**936047**	**950181**	**941860**	**900326**	**833867**	**806385**	**782247**	**742604**	**714997**	**744879**	**778988**	**793313**	**782885**	**0,1**	**-1,2**	**-0,6**	**-0,9**	**0,9**	**0,0**
Solids	366477	277810	213423	196277	177999	167124	133606	105175	74570	49694	40615	42623	41972	-5,3	-1,8	-2,8	-5,7	-5,9	0,3
Oil	129551	171052	173006	134290	104398	73701	46270	35888	31924	22671	14122	6825	2229	2,9	-4,9	-7,8	-3,6	-7,8	-16,9
Natural gas	162447	188965	207559	188677	164866	129039	110511	89429	72639	58928	47180	33038	23566	2,5	-2,3	-3,9	-4,1	-4,2	-6,7
Nuclear	202589	223028	243761	257360	235016	237360	229121	218234	202468	231475	244015	237692	216897	1,9	-0,4	-0,3	-1,2	1,9	-1,2
Renewable energy sources	74984	89326	104111	123722	151588	199161	262739	293879	333395	382111	433056	473134	498221	3,3	3,8	5,7	2,4	2,6	1,4
Hydro	25101	28054	30374	26395	30008	30276	30808	31569	32129	32612	33132	33587	33949	1,9	-0,1	0,3	0,4	0,3	0,2
Biomass & Waste	46473	57201	67982	85129	98965	122967	149650	159101	164958	193397	216805	238746	246615	3,9	3,8	4,2	1,0	2,8	1,3
Wind	67	350	1913	6061	12781	28237	52499	65906	86270	98019	115112	124712	135662	39,8	20,9	15,2	5,1	2,9	1,7
Solar and others	153	274	421	807	3436	9380	18834	24906	32945	38957	47498	53628	58134	10,7	23,3	18,5	5,8	3,7	2,0
Geothermal	3190	3447	3421	5331	6398	8301	10949	12396	17094	19125	20509	22461	23861	0,7	6,5	5,5	4,6	1,8	1,5
Net Imports	**756079**	**738600**	**826299**	**986048**	**969437**	**1048749**	**952256**	**910645**	**868793**	**732708**	**629866**	**552711**	**496822**	**0,9**	**1,6**	**-0,2**	**-0,9**	**-3,2**	**-2,3**
Solids	81846	79338	98645	126639	103003	116164	86465	68874	39638	13851	1793	-3503	14624	1,9	0,4	-1,7	-7,5	-26,6	23,4
Oil	535645	512185	533039	599851	580674	608334	582557	556019	530722	440649	345390	255622	196721	0,0	0,9	0,0	-0,9	-4,2	-5,5
- Crude oil and Feedstocks	508460	494000	513725	581995	578242	602274	577961	555450	533431	449575	355767	277010	218651	0,1	1,2	0,0	-0,8	-4,0	-4,8
- Oil products	27185	18185	19314	17856	2432	6060	4596	569	-2710	-8927	-10377	-21388	-21930	-3,4	-18,7	6,6			
Natural gas	135121	145288	192531	257366	278078	317239	271247	279361	291381	268296	271060	284030	264006	3,6	3,7	-0,2	0,7	-0,7	-0,3
Electricity	3323	1508	1686	971	696	-620	-2172	-2596	-1495	-1775	-1859	-1911	-2329	-6,6	-8,5				
Renewable energy forms	144	279	397	1222	6987	7633	14159	8987	8547	11689	13483	18473	23800	10,7	33,2	7,3	-4,9	4,7	5,8
Gross Inland Consumption	**1660159**	**1662517**	**1723099**	**1825989**	**1753252**	**1803017**	**1681588**	**1600538**	**1531898**	**1430568**	**1364649**	**1303197**	**1237672**	**0,4**	**0,2**	**-0,4**	**-0,9**	**-1,1**	**-1,0**
Solids	452940	364248	321007	319922	281002	283287	220071	174049	114209	63545	42408	39120	56596	-3,4	-1,3	-2,4	-6,3	-9,4	2,9
Oil	631058	650858	658727	676859	635020	629918	575912	539195	511306	419492	323152	233738	174438	0,4	-0,4	-1,0	-1,2	-4,5	-6,0
Natural gas	294905	333268	393417	445998	442944	446277	381758	368790	364020	327224	318239	317068	287572	2,9	1,2	-1,5	-0,5	-1,3	-1,0
Nuclear	202589	223028	243761	257360	235016	237360	229121	218234	202468	231475	244015	237692	216897	1,9	-0,4	-0,3	-1,2	1,9	-1,2
Electricity	3323	1508	1686	971	696	-620	-2172	-2596	-1495	-1775	-1859	-1911	-2329	-6,6	-8,5				
Renewable energy forms	75343	89606	104501	124880	158574	206794	276898	302865	341391	390608	438694	477489	504498	3,3	4,3	5,7	2,1	2,5	1,4
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	16,0	15,7	13,1	10,9	7,5	4,4	3,1	3,0	4,6						
Oil	38,0	39,1	38,2	37,1	36,2	34,9	34,2	33,7	33,4	29,3	23,7	17,9	14,1						
Natural gas	17,8	20,0	22,8	24,4	25,3	24,8	22,7	23,0	23,8	22,9	23,3	24,3	23,2						
Nuclear	12,2	13,4	14,1	14,1	13,4	13,2	13,6	13,6	13,2	16,2	17,9	18,2	17,5						
Renewable energy forms	4,5	5,4	6,1	6,8	9,0	11,5	16,5	18,9	22,3	27,3	32,1	36,6	40,8						
Gross Electricity Generation in GWh_e	**2562823**	**2712209**	**2991720**	**3274121**	**3320232**	**3622963**	**3676708**	**3761247**	**3747228**	**3940991**	**4353762**	**4593478**	**4872341**	**1,6**	**1,0**	**1,0**	**0,2**	**1,5**	**1,1**
Nuclear	794718	881662	944823	997519	911418	921018	892305	861315	803812	932416	987532	970241	935346	1,7	-0,4	-0,2	-1,0	2,1	-0,5
Hydro & wind	292648	330306	375545	378836	514979	713811	1042328	1245697	1564951	1770491	2068888	2259430	2454950	2,5	3,2	7,3	4,1	2,8	1,7
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1893835	1988135	1742075	1654234	1378465	1238085	1297342	1363807	1482045	1,3	1,3	-0,8	-2,3	-0,6	1,3
Fuel Inputs for Thermal Power Generation	**383492**	**362334**	**382613**	**424208**	**412247**	**427642**	**375988**	**351192**	**301418**	**271283**	**279041**	**289489**	**306228**	**0,0**	**0,7**	**-0,9**	**-2,2**	**-0,8**	**0,9**
Solids	263837	230040	223012	229245	209696	213286	156039	116096	61973	32175	22100	28286	50501	-1,7	-0,6	-2,9	-8,8	-9,8	8,6
Oil (including refinery gas)	54404	51463	39294	29780	15655	14092	8297	9759	9226	8443	7380	4179	384	-3,2	-8,8	-6,2	1,1	-2,2	-25,6
Gas	56754	67806	102408	134637	145953	140938	125048	128301	122409	113218	120162	120907	119922	6,1	3,6	-1,5	-0,2	-0,2	0,0
Biomass & Waste	5724	10033	14960	25901	35542	52522	78058	87794	93906	102341	113230	118669	117637	10,1	9,0	8,2	1,9	1,9	0,4
Geothermal heat	2774	2992	2939	4645	5400	6804	8546	9240	13904	15106	16169	17448	17743	0,6	6,3	4,7	5,0	1,5	0,9
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0	0	0	0	41						
Fuel Input in other transformation proc.	**839073**	**814654**	**827098**	**842975**	**793682**	**794123**	**744759**	**707996**	**677216**	**584335**	**477770**	**387931**	**326515**	**-0,1**	**-0,4**	**-0,6**	**-0,9**	**-3,4**	**-3,7**
Refineries	679426	705954	735244	758152	718075	711235	658854	624792	597431	502676	396234	298395	227316	0,8	-0,2	-0,9	-1,0	-4,0	-5,4
Biofuels and hydrogen production	2	202	610	3129	12206	19490	26745	25790	25703	44990	59174	75061	90453	79,6	34,9	8,2	-0,4	8,7	4,3
District heating	32960	23240	19323	16212	15970	15644	13844	13201	11307	10760	7205	4860	3443	-5,2	-1,9	-1,4	-2,0	-4,4	-7,1
Others	126685	85258	71921	65482	47431	47753	45316	44213	42775	25908	15158	9616	5304	-5,5	-4,1	-0,5	-0,6	-9,9	-10,0
Energy Branch Consumption	**82379**	**88696**	**88176**	**96033**	**91103**	**90108**	**83563**	**77664**	**72262**	**64800**	**59023**	**56033**	**62866**	**0,7**	**0,3**	**-0,9**	**-1,4**	**-2,0**	**0,6**
Non-Energy Uses	**97931**	**110541**	**112495**	**117477**	**111508**	**115320**	**118130**	**119715**	**121502**	**121019**	**120132**	**112308**	**105651**	**1,4**	**-0,1**	**0,6**	**0,3**	**-0,1**	**-1,3**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173676**	**1160719**	**1214911**	**1145539**	**1098479**	**1073123**	**979418**	**906948**	**853415**	**796953**	**0,4**	**0,4**	**-0,1**	**-0,7**	**-1,7**	**-1,3**
by sector																			
Industry	365650	328513	326949	326308	310867	322893	317727	315774	315746	304794	301680	286024	273050	-1,1	-0,5	0,2	-0,1	-0,5	-1,0
- energy intensive industries	234722	214526	213112	210991	192045	196810	190595	187117	184911	172601	165966	153150	141629	-1,0	-1,0	-0,1	-0,3	-1,1	-1,6
- other industrial sectors	130928	113987	113837	115317	118822	126082	127133	128658	130835	132193	135714	132874	131421	-1,4	0,4	0,7	0,3	0,4	-0,3
Residential	264307	280418	286784	308104	306277	320909	289992	272097	263833	237654	220271	208125	186747	0,8	0,7	-0,5	-0,9	-1,8	-1,6
Tertiary	158484	160442	159866	176859	173611	183954	167277	152932	146319	127074	116899	112028	104394	0,1	0,8	-0,4	-1,3	-2,2	-1,1
Transport	280269	300617	339389	362405	369965	387156	370542	357676	347225	309896	268098	247238	232762	1,9	0,9	0,0	-0,6	-2,6	-1,4
by fuel																			
Solids	125031	84977	61454	54486	47313	44817	39498	33100	26905	15091	10585	4716	2465	-6,9	-2,6	-1,8	-3,8	-8,9	-13,6
Oil	444429	456959	478882	495857	476944	476736	433195	401949	377958	298182	216449	157751	119008	0,7	0,0	-1,0	-1,4	-5,4	-5,8
Gas	227902	245996	265552	283524	268007	275220	227782	209417	211385	176861	152774	135736	101462	1,5	0,1	-1,6	-0,7	-3,2	-4,0
Electricity	184145	193367	216403	237537	242353	265245	269920	276873	278937	288677	307654	310406	308281	1,6	1,1	1,1	0,3	1,0	0,0
Heat (from CHP and District Heating) [(A)]	48610	44616	40061	44441	57826	71764	79088	82821	83257	82387	80019	77480	76437	-1,9	3,7	3,2	0,5	-0,4	-0,5
Other	38592	44073	50640	57832	68276	81129	96056	94319	94681	118220	139467	167325	189301	2,8	3,0	3,5	-0,1	3,9	3,1
CO_2 Emissions (Mt of CO_2 - sec approach)	**4030,6**	**3800,1**	**3810,6**	**3946,6**	**3689,7**	**3682,8**	**3098,2**	**2771,6**	**2430,3**	**1831,0**	**1374,9**	**993,4**	**668,6**	**-0,6**	**-0,3**	**-1,7**	**-2,4**	**-5,5**	**-7,0**
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1274,9	1273,5	969,6	818,5	578,3	379,7	263,1	136,0	30,3	-1,2	-0,4	-2,7	-5,0	-7,6	-19,4
Energy Branch	152,2	171,0	170,2	181,6	157,2	145,9	127,6	113,4	102,9	74,6	57,5	44,2	32,0	1,1	-0,8	-2,1	-2,1	-5,7	-5,7
Industry	781,4	678,1	623,0	581,9	497,5	480,1	435,1	414,5	405,9	332,9	290,8	234,3	176,2	-2,2	-2,2	-1,3	-0,7	-3,3	-4,9
Residential	499,4	481,6	466,2	486,7	466,4	466,2	383,9	325,0	308,6	229,5	167,8	125,0	74,1	-0,7	0,0	-1,9	-2,2	-5,9	-7,8
Tertiary	300,5	275,3	242,0	262,2	245,5	239,3	188,8	163,4	155,3	118,6	85,7	62,1	39,3	-2,1	0,1	-2,6	-1,9	-5,8	-7,5
Transport	812,7	872,9	988,5	1053,1	1048,2	1077,7	993,1	936,9	879,3	695,8	510,0	391,7	316,7	2,0	0,6	-0,5	-1,2	-5,3	-4,7
CO_2 Emissions Index (1990=100)	**100,0**	**94,3**	**94,5**	**97,9**	**91,5**	**91,4**	**76,9**	**68,8**	**60,3**	**45,4**	**34,1**	**24,6**	**16,6**						
CO_2 Emissions (Mt of CO_2 - ref approach)	**4172,0**	**3950,7**	**3922,7**	**4087,6**	**3757,0**	**3750,6**	**3166,2**	**2838,5**	**2498,9**	**1893,9**	**1440,7**	**1082,8**	**774,3**	**-0,6**	**-0,4**	**-1,7**	**-2,3**	**-5,4**	**-6,0**

EU27: Delayed CCS scenario														SUMMARY ENERGY BALANCE AND INDICATORS (B)					
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12750,3	14164,0	15503,7	16824,7	18157,1	19527,9	21002,9	22560,0	2,2	1,2	2,2	1,7	1,5	1,5
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	154,0	141,4	118,7	103,2	91,1	78,8	69,9	62,0	54,9	-1,8	-1,0	-2,6	-2,6	-2,6	-2,4
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,51	3,55	3,27	3,09	2,95	2,75	2,62	2,51	2,40	0,1	-0,2	-0,7	-1,0	-1,2	-0,9
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6649	7136	7155	7264	7207	7569	8371	8862	9455	1,3	0,7	0,7	0,1	1,5	1,2
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,10	2,04	1,84	1,73	1,59	1,28	1,01	0,76	0,54	-0,9	-0,5	-1,3	-1,5	-4,4	-6,0
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,39	7,25	6,03	5,35	4,67	3,52	2,64	1,92	1,30	-0,8	-0,7	-2,0	-2,5	-5,5	-6,9
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	324,1	288,8	218,7	178,8	144,4	100,8	70,4	47,3	29,6	-2,7	-1,5	-3,9	-4,1	-6,9	-8,3
Import Dependency %	44,6	43,5	46,8	52,5	53,8	56,5	54,9	55,1	54,9	49,6	44,7	41,1	38,8						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	89,8	84,6	75,4	68,9	64,0	57,5	53,2	47,2	42,1	-2,6	-1,1	-1,7	-1,6	-1,8	-2,3
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,2	89,6	73,3	63,5	57,2	47,2	40,8	35,6	29,9	-1,3	-0,4	-2,7	-2,5	-3,3	-3,1
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	93,9	88,0	71,8	59,7	52,4	42,1	35,8	31,8	27,5	-2,3	-0,6	-2,7	-3,1	-3,7	-2,6
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	90,4	77,9	68,7	61,5	50,8	40,9	35,1	30,7	-0,2	-0,3	-2,1	-2,3	-4,0	-2,8
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,31	0,27	0,20	0,17	0,12	0,07	0,05	0,02	0,01	-2,1	-1,9	-4,1	-5,2	-8,5	
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,94	1,86	1,75	1,67	1,63	1,41	1,16	0,95	0,76	-0,7	-0,7	-1,1	-0,7	-3,3	-4,2
Industry	2,14	2,06	1,91	1,78	1,60	1,49	1,37	1,31	1,29	1,09	0,96	0,82	0,65	-1,1	-1,7	-1,5	-0,6	-2,8	-3,9
Residential	1,89	1,72	1,63	1,58	1,52	1,45	1,32	1,19	1,17	0,97	0,76	0,60	0,40	-1,5	-0,7	-1,4	-1,2	-4,2	-6,3
Tertiary	1,90	1,72	1,51	1,48	1,41	1,30	1,13	1,07	1,06	0,93	0,73	0,55	0,38	-2,2	-0,7	-2,2	-0,6	-3,6	-6,5
Transport	2,90	2,90	2,91	2,91	2,83	2,78	2,68	2,62	2,53	2,25	1,90	1,58	1,36	0,0	-0,3	-0,6	-0,6	-2,8	-3,3
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654168**	**715466**	**821505**	**926251**	**1029593**	**1076048**	**1199296**	**1286867**	**1445606**	**1536466**	**1638739**		**2,3**	**2,3**	**1,5**	**1,9**	**1,3**
Nuclear energy			133966	134452	131393	125743	124707	106393	106421	122512	130739	131701	126606		-0,2	-0,5	-1,6	2,1	-0,3
Renewable energy			112878	147262	206776	283876	420035	503365	648548	744990	891318	989081	1093433		6,2	7,3	4,4	3,2	2,1
Hydro (pumping excluded)			99714	104505	107315	111550	114915	116917	118978	121120	122702	124346	126055		0,7	0,7	0,3	0,3	0,3
Wind			12793	40584	83905	143733	247153	302574	391801	442429	515971	557736	608692		20,7	11,4	4,7	2,8	1,7
Solar			371	2172	15307	28018	56235	80894	133467	175455	245538	298509	348458		45,1	13,9	9,0	6,3	3,6
Other renewables (tidal etc.)			0	1	249	575	1732	2981	4302	5986	7108	8491	10228			21,4	9,5	5,1	3,7
Thermal power			407324	433752	483337	516631	484851	466290	444327	419365	423549	415684	418700		1,7	0,0	-0,9	-0,5	-0,1
of which cogeneration units			76247	85453	98258	119251	124528	132706	141144	158032	163436	153848	150789		2,6	2,4	1,3	1,5	-0,8
of which CCS units			0	0	0	0	2657	2657	2862	8816	37677	81789	147663				0,7	29,4	14,6
Solids fired			194165	186620	183624	182691	154302	128370	107078	84751	70835	67409	73335		-0,6	-1,7	-3,6	-4,0	0,3
Gas fired			129444	166863	218517	242663	232712	232853	230370	220033	222262	212082	209830		5,4	0,6	-0,1	-0,4	-0,6
Oil fired			71058	62082	55901	46066	34927	32601	28143	24422	21533	19758	18477		-2,4	-4,6	-2,1	-2,6	-1,5
Biomass-waste fired			12051	17502	24567	44304	61771	71235	76886	88149	106768	114115	114699		7,4	9,7	2,2	3,3	0,7
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	686	727	908	1139	1231	1850	2010	2151	2320	2360		1,9	4,6	5,0	1,5	0,9
Load factor for net electric capacities (%)			49,1	49,1	43,9	42,6	39,0	38,4	34,5	33,8	33,1	32,5	32,0						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,5	40,0	39,8	40,5	39,3	39,2	40,0	40,5	41,6						
CHP indicator (% of electricity from CHP)			11,4	11,7	14,9	19,0	20,3	21,0	20,6	19,4	17,1	15,4	14,2						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	0,6	0,6	0,7	2,2	6,3	12,0	19,0						
Non fossil fuels in electricity generation (%)			45,8	44,8	47,2	50,7	60,8	65,3	73,2	79,1	81,0	81,2	79,9						
- nuclear			31,6	30,5	27,5	25,4	24,3	22,9	21,5	23,7	22,7	21,1	19,2						
- renewable energy forms and industrial waste			14,2	14,3	19,7	25,3	36,5	42,4	51,7	55,4	58,3	60,0	60,7						
Indicators for renewables (excluding industrial waste) (%) [B]																			
RES in gross final energy demand (%)			7,6	8,6	11,4	14,8	21,3	24,4	28,0	35,0	42,6	49,3	55,7						
RES in transport (%)			0,5	1,4	4,3	6,6	10,8	13,8	18,7	30,7	44,8	55,1	62,2						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**7132,6**	**7480,0**	**7913,9**	**8355,1**	**8560,1**	**8778,9**	**9046,4**	**9246,8**	**1,9**	**1,0**	**1,4**	**1,1**	**0,5**	**0,5**
Public road transport	544,0	504,0	517,6	526,0	545,0	573,7	639,6	675,1	721,5	770,2	812,8	850,1	885,5	-0,5	0,5	1,6	1,2	1,2	0,9
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,0	5288,3	5414,7	5648,9	5886,0	5915,0	5980,5	6072,8	6126,7	2,4	0,9	1,1	0,8	0,2	0,2
Rail	472,5	421,7	447,9	461,0	482,5	525,5	607,0	645,1	704,0	765,4	821,9	891,8	964,6	-0,5	0,7	2,3	1,5	1,6	1,6
Aviation	317,3	351,3	456,9	527,3	576,9	702,8	775,7	899,7	996,3	1060,1	1112,4	1178,5	1215,4	3,7	2,4	3,0	2,5	1,1	0,9
Inland navigation	45,8	44,4	41,7	39,5	40,8	42,5	43,1	45,0	47,4	49,4	51,3	53,1	54,6	-0,9	-0,2	0,6	0,9	0,8	0,6
Travel per person (km per capita)	10376	11127	12248	12756	13038	14048	14557	15283	16069	16441	16879	17452	17944	1,7	0,6	1,1	1,0	0,5	0,6
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2952,5**	**3058,3**	**3212,4**	**3372,9**	**3425,4**	**3520,0**	**3610,5**	**3657,4**	**1,7**	**1,9**	**1,4**	**1,0**	**0,4**	**0,4**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2164,4	2155,4	2255,1	2346,9	2323,1	2341,6	2366,1	2353,6	3,7	2,5	1,1	0,9	0,0	0,1
Rail	526,3	386,1	403,7	414,1	440,5	489,1	575,1	608,2	658,0	715,2	775,1	826,0	873,5	-2,6	0,9	2,7	1,4	1,7	1,2
Inland navigation	261,6	267,6	273,3	280,2	281,9	299,0	327,8	349,1	368,0	387,2	403,3	418,4	430,3	0,4	0,3	1,5	1,2	0,9	0,6
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	232	216	207	200	189	180	172	162	-0,4	0,7	-0,8	-0,7	-1,1	-1,1
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**369965**	**387156**	**370542**	**357676**	**347225**	**309896**	**268098**	**247238**	**232762**	**1,9**	**0,9**	**0,0**	**-0,6**	**-2,6**	**-1,4**
Public road transport	5197	4732	4914	5039	5182	5315	5423	5238	4922	4142	3401	3287	3262	-0,6	0,5	0,5	-1,0	-3,6	-0,4
Private cars and motorcycles	154395	166321	182974	187736	186407	184714	167418	148669	139189	123023	96945	85240	74097	1,7	0,2	-1,1	-1,8	-3,6	-2,7
Trucks	74969	79037	90951	105104	111606	123128	119072	121502	121946	109612	96681	88458	84019	2,0	2,1	0,6	0,2	-2,3	-1,4
Rail	9560	9452	9600	9436	9594	10160	11029	10599	9635	9281	8671	8127	7909	0,0	0,0	1,4	-1,3	-1,0	-0,9
Aviation	29038	34112	45395	49703	51709	58141	61531	65280	64824	57081	55657	55427	56812	4,6	1,3	1,8	0,5	-1,5	0,2
Inland navigation	7110	6963	5555	5386	5466	5699	6071	6387	6709	6758	6743	6699	6663	-2,4	-0,2	1,1	1,0	0,1	-0,1
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	35,4	31,9	28,2	25,5	22,0	18,2	16,4	15,0	0,2	-0,6	-1,7	-2,2	-3,3	-2,0
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,0	45,7	43,2	41,8	39,7	35,4	30,7	27,5	25,8	-0,2	-0,1	-0,6	-0,8	-2,5	-1,7

6. Low nuclear scenario

EU27: Low nuclear scenario														SUMMARY ENERGY BALANCE AND INDICATORS (A)					
ktoe	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**'90-'00**	**'00-'10**	**'10-'20**	**'20-'30**	**'30-'40**	**'40-'50**
														Annual % Change					
Production	**936047**	**950181**	**941860**	**900326**	**833880**	**806302**	**783208**	**729856**	**655412**	**634719**	**652843**	**647364**	**647871**	**0,1**	**-1,2**	**-0,6**	**-1,8**	**0,0**	**-0,1**
Solids	366477	277810	213423	196277	177975	167224	136642	110080	83810	81928	83306	78964	73504	-5,3	-1,8	-2,6	-4,8	-0,1	-1,2
Oil	129551	171052	173006	134290	104398	73687	46256	35838	31856	23740	14974	7052	2225	2,9	-4,9	-7,8	-3,7	-7,3	-17,4
Natural gas	162447	188965	207559	188677	164866	129038	110475	89793	73132	61058	48751	33622	22827	2,5	-2,3	-3,9	-4,0	-4,0	-7,3
Nuclear	202589	223028	243761	257360	235016	237465	227497	199311	125368	79056	62962	37271	29326	1,9	-0,4	-0,3	-5,8	-6,7	-7,4
Renewable energy sources	74984	89326	104111	123722	151625	198889	262338	294836	341246	388937	442850	490455	519989	3,3	3,8	5,6	2,7	2,6	1,6
Hydro	25101	28054	30374	26395	30008	30274	30795	31570	32111	32594	33116	33579	33949	1,9	-0,1	0,3	0,4	0,3	0,2
Biomass & Waste	46473	57201	67982	85129	99000	122712	149289	159128	167569	191670	215871	241554	251459	3,9	3,8	4,2	1,2	2,6	1,5
Wind	67	350	1913	6061	12781	28217	52300	66202	89644	103804	122309	135561	148699	39,8	20,9	15,1	5,5	3,2	2,0
Solar and others	153	274	421	807	3438	9384	18817	24998	33382	40619	50366	56988	61610	10,7	23,4	18,5	5,9	4,2	2,0
Geothermal	3190	3447	3421	5331	6399	8302	11137	12937	18541	20250	21188	22774	24271	0,7	6,5	5,7	5,2	1,3	1,4
Net Imports	**756079**	**738600**	**826299**	**986048**	**969296**	**1048783**	**956523**	**912998**	**884995**	**824651**	**740294**	**632191**	**531930**	**0,9**	**1,6**	**-0,1**	**-0,8**	**-1,8**	**-3,3**
Solids	81846	79338	98645	126639	102765	116218	91199	70928	45170	48601	51530	40660	42204	1,9	0,4	-1,2	-6,8	1,3	-2,0
Oil	535645	512185	533039	599851	580732	608318	582774	555199	530926	459431	365668	263723	195890	0,0	0,9	0,0	-0,9	-3,7	-6,1
- Crude oil and Feedstocks	508460	494000	513725	581995	578269	602162	578385	555029	534076	465431	374988	285683	218147	0,1	1,2	0,0	-0,8	-3,5	-5,3
- Oil products	27185	18185	19314	17856	2463	6155	4390	171	-3150	-6000	-9320	-21960	-22257	-3,4	-18,6	6,0			
Natural gas	135121	145288	192531	257366	278116	317218	270529	280183	301835	306217	311090	310690	271546	3,6	3,7	-0,3	1,1	0,3	-1,4
Electricity	3323	1508	1686	971	696	-620	-2153	-2586	-1280	-839	-1192	-1292	-1457	-6,6	-8,5				
Renewable energy forms	144	279	397	1222	6987	7649	14174	9273	8344	11241	13199	18409	23747	10,7	33,2	7,3	-5,2	4,7	6,0
Gross Inland Consumption	**1660159**	**1662517**	**1723099**	**1825989**	**1753125**	**1802969**	**1686817**	**1590142**	**1488516**	**1410951**	**1346846**	**1235421**	**1137200**	**0,4**	**0,2**	**-0,4**	**-1,2**	**-1,0**	**-1,7**
Solids	452940	364248	321007	319922	280741	283442	227841	181007	128981	130529	134836	119624	115708	-3,4	-1,3	-2,1	-5,5	0,4	-1,5
Oil	631058	650858	658727	676859	635078	629888	576116	538325	511443	437880	342273	241138	173496	0,4	-0,4	-1,0	-1,2	-3,9	-6,6
Natural gas	294905	333268	393417	445998	442981	446256	381003	369976	374967	367275	359841	344312	294373	2,9	1,2	-1,5	-0,2	-0,4	-2,0
Nuclear	202589	223028	243761	257360	235016	237465	227497	199311	125368	79056	62962	37271	29326	1,9	-0,4	-0,3	-5,8	-6,7	-7,4
Electricity	3323	1508	1686	971	696	-620	-2153	-2586	-1280	-839	-1192	-1292	-1457	-6,6	-8,5				
Renewable energy forms	75343	89606	104501	124880	158613	206538	276512	304109	349038	397050	448127	494367	525755	3,3	4,3	5,7	2,4	2,5	1,6
as % in Gross Inland Consumption																			
Solids	27,3	21,9	18,6	17,5	16,0	15,7	13,5	11,4	8,7	9,3	10,0	9,7	10,2						
Oil	38,0	39,1	38,2	37,1	36,2	34,9	34,2	33,9	34,4	31,0	25,4	19,5	15,3						
Natural gas	17,8	20,0	22,8	24,4	25,3	24,8	22,6	23,3	25,2	26,0	26,7	27,9	25,9						
Nuclear	12,2	13,4	14,1	14,1	13,4	13,2	13,5	12,5	8,4	5,6	4,7	3,0	2,6						
Renewable energy forms	4,5	5,4	6,1	6,8	9,0	11,5	16,4	19,1	23,4	28,1	33,3	40,0	46,2						
Gross Electricity Generation in GWh_e	**2562823**	**2712209**	**2991720**	**3274121**	**3319118**	**3622155**	**3692684**	**3749635**	**3684346**	**4003032**	**4530075**	**4732533**	**4852610**	**1,6**	**1,0**	**1,1**	**0,0**	**2,1**	**0,7**
Nuclear	794718	881662	944823	997519	911418	921451	885417	779772	492435	313482	251187	151146	120339	1,7	-0,4	-0,3	-5,7	-6,5	-7,1
Hydro & wind	292648	330306	375545	378836	514979	713551	1039903	1250333	1608849	1848852	2175334	2418050	2646680	2,5	3,2	7,3	4,5	3,1	2,0
Thermal (incl. biomass)	1475456	1500241	1671352	1897765	1892721	1987153	1767363	1719529	1583062	1840698	2103554	2163336	2085591	1,3	1,3	-0,7	-1,1	2,9	-0,1
Fuel Inputs for Thermal Power Generation	**383492**	**362334**	**382613**	**424208**	**412058**	**427495**	**382177**	**362656**	**335562**	**367803**	**399473**	**395402**	**379404**	**0,0**	**0,7**	**-0,7**	**-1,3**	**1,8**	**-0,5**
Solids	263837	230040	223012	229245	209496	213465	162971	123186	76816	91592	105773	106405	109961	-1,7	-0,6	-2,5	-7,2	3,3	0,4
Oil (including refinery gas)	54404	51463	39294	29780	15656	14147	8067	10169	10353	10963	10330	5005	485	-3,2	-8,8	-6,4	2,5	0,0	-26,4
Gas	56754	67806	102408	134637	145959	140766	124249	130766	134700	145212	152853	147900	137605	6,1	3,6	-1,6	0,8	1,3	-1,0
Biomass & Waste	5724	10033	14960	25901	35546	52312	78156	88761	98393	103707	113533	118393	113326	10,1	9,0	8,2	2,3	1,4	0,0
Geothermal heat	2774	2992	2939	4645	5400	6804	8733	9773	15299	16328	16985	17700	18008	0,6	6,3	4,9	5,8	1,1	0,6
Hydrogen - Methanol	0	0	0	0	0	0	0	0	0	0	0	0	19						
Fuel Input in other transformation proc.	**839073**	**814654**	**827098**	**842975**	**793665**	**794095**	**745841**	**707244**	**678415**	**607425**	**509797**	**401404**	**325061**	**-0,1**	**-0,4**	**-0,6**	**-0,9**	**-2,8**	**-4,4**
Refineries	679426	705954	735244	758152	718103	711109	659266	624319	598003	519578	416258	307345	226788	0,8	-0,2	-0,9	-1,0	-3,6	-5,9
Biofuels and hydrogen production	2	202	610	3129	12208	19510	26828	25818	25726	44241	61725	77999	90412	79,6	34,9	8,2	-0,4	9,1	3,9
District heating	32960	23240	19323	16212	15962	15725	13843	13081	11533	9119	6389	4527	3004	-5,2	-1,9	-1,4	-1,8	-5,7	-7,3
Others	126685	85258	71921	65482	47391	47751	45903	44025	43154	34487	25425	11533	4857	-5,5	-4,1	-0,3	-0,6	-5,2	-15,3
Energy Branch Consumption	**82379**	**88696**	**88176**	**96033**	**91094**	**90076**	**83701**	**77476**	**72395**	**73565**	**74797**	**71351**	**66487**	**0,7**	**0,3**	**-0,8**	**-1,4**	**0,3**	**-1,2**
Non-Energy Uses	**97931**	**110541**	**112495**	**117477**	**111511**	**115318**	**118137**	**119710**	**121465**	**120967**	**120103**	**112174**	**105679**	**1,4**	**-0,1**	**0,6**	**0,3**	**-0,1**	**-1,3**
Final Energy Demand	**1068710**	**1069989**	**1112989**	**1173676**	**1160743**	**1214869**	**1147435**	**1095212**	**1065310**	**1011338**	**946291**	**868740**	**793419**	**0,4**	**0,4**	**-0,1**	**-0,7**	**-1,2**	**-1,7**
by sector																			
Industry	365650	328513	326949	326308	310858	322787	318753	315293	313987	307432	305065	286550	271549	-1,1	-0,5	0,3	-0,2	-0,3	-1,2
- energy intensive industries	234722	214526	213112	210991	192040	196748	191503	186743	183733	175684	169784	154005	140471	-1,0	-1,0	0,0	-0,4	-0,8	-1,9
- other industrial sectors	130928	113987	113837	115317	118818	126039	127250	128550	130254	131748	135281	132545	131078	-1,4	0,4	0,7	0,2	0,4	-0,3
Residential	264307	280418	286784	308104	306318	320952	290108	270925	261270	248474	232717	212334	185477	0,8	0,7	-0,5	-1,0	-1,2	-2,2
Tertiary	158484	160442	159866	176859	173603	183981	167740	152016	143445	134612	125926	114755	102850	0,1	0,8	-0,3	-1,6	-1,3	-2,0
Transport	280269	300617	339389	362405	369964	387148	370834	356978	346607	320820	282583	255101	233542	1,9	0,9	0,0	-0,7	-2,0	-1,9
by fuel																			
Solids	125031	84977	61454	54486	47270	44790	40209	32886	26273	17616	13511	5906	2239	-6,9	-2,6	-1,6	-4,2	-6,4	-16,5
Oil	444429	456959	478882	495857	476999	476739	433211	400710	377138	313365	232377	164064	117903	0,7	0,0	-1,0	-1,4	-4,7	-6,6
Gas	227902	245996	265552	283524	268025	275255	228194	208413	210001	189505	166301	137513	95784	1,5	0,1	-1,6	-0,8	-2,3	-5,4
Electricity	184145	193367	216403	237537	242283	265184	271120	276033	274027	287361	307103	307121	305497	1,6	1,1	1,1	0,1	1,1	-0,1
Heat (from CHP and District Heating) [A]	48610	44616	40061	44441	57849	71838	79028	83235	84786	87142	86190	82369	79380	-1,9	3,7	3,2	0,7	0,2	-0,8
Other	38592	44073	50640	57832	68316	81063	95672	93936	93084	116348	140809	171767	192616	2,8	3,0	3,4	-0,3	4,2	3,2
CO_2 Emissions (Mt of CO_2 - sec approach)	**4030,6**	**3800,1**	**3810,6**	**3946,6**	**3688,9**	**3683,2**	**3131,7**	**2796,9**	**2481,5**	**1993,9**	**1495,0**	**986,5**	**634,3**	**-0,6**	**-0,3**	**-1,6**	**-2,3**	**-4,9**	**-8,2**
Power generation/District heating	1484,3	1321,2	1320,8	1381,1	1274,2	1273,9	998,2	851,2	637,7	449,5	284,9	98,8	21,2	-1,2	-0,4	-2,4	-4,4	-7,7	-22,9
Energy Branch	152,2	171,0	170,2	181,6	157,2	145,9	128,4	113,0	103,1	79,7	61,0	45,6	24,4	1,1	-0,8	-2,0	-2,2	-5,1	-8,7
Industry	781,4	678,1	623,0	581,9	497,0	480,0	439,5	412,8	404,1	349,1	308,2	234,9	165,5	-2,2	-2,2	-1,2	-0,8	-2,7	-6,0
Residential	499,4	481,6	466,2	486,7	466,7	466,4	383,8	322,8	304,8	255,7	194,5	132,9	70,8	-0,7	0,0	-1,9	-2,3	-4,4	-9,6
Tertiary	300,5	275,3	242,0	262,2	245,7	239,4	188,2	162,4	154,1	133,5	102,0	68,3	38,2	-2,1	0,2	-2,6	-2,0	-4,0	-9,4
Transport	812,7	872,9	988,5	1053,1	1048,2	1077,6	993,7	934,7	877,7	726,3	544,5	406,0	314,2	2,0	0,6	-0,5	-1,2	-4,7	-5,3
CO_2 Emissions Index (1990=100)	**100,0**	**94,3**	**94,5**	**97,9**	**91,5**	**91,4**	**77,7**	**69,4**	**61,6**	**49,5**	**37,1**	**24,5**	**15,7**						
CO_2 Emissions (Mt of CO_2 - ref approach)	**4172,0**	**3950,7**	**3922,7**	**4087,6**	**3756,3**	**3751,1**	**3199,3**	**2863,6**	**2550,6**	**2056,8**	**1560,2**	**1073,7**	**737,6**	**-0,6**	**-0,4**	**-1,6**	**-2,2**	**-4,8**	**-7,2**

EU27: Low nuclear scenario													SUMMARY ENERGY BALANCE AND INDICATORS (B)					
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'90-'00	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
														Annual % Change					
Main Energy System Indicators																			
Population (Million)	470,388	477,010	481,072	489,211	499,389	507,727	513,838	517,811	519,942	520,654	520,103	518,362	515,303	0,2	0,4	0,3	0,1	0,0	-0,1
GDP (in 000 MEuro'05)	8142,7	8748,4	10107,2	11063,1	11385,6	12750,3	14164,0	15503,7	16824,7	18157,1	19527,9	21002,9	22560,0	2,2	1,2	2,2	1,7	1,5	1,5
Gross Inl. Cons./GDP (toe/MEuro'05)	203,9	190,0	170,5	165,1	154,0	141,4	119,1	102,6	88,5	77,7	69,0	58,8	50,4	-1,8	-1,0	-2,5	-2,9	-2,5	-3,1
Gross Inl. Cons./Capita (toe/inhabitant)	3,53	3,49	3,58	3,73	3,51	3,55	3,28	3,07	2,86	2,71	2,59	2,38	2,21	0,1	-0,2	-0,7	-1,4	-1,0	-1,6
Electricity Generated/Capita (kWh gross/inhabitant)	5448	5686	6219	6693	6646	7134	7186	7241	7086	7688	8710	9130	9417	1,3	0,7	0,8	-0,1	2,1	0,8
Carbon intensity (t of CO_2/toe of GIC)	2,43	2,29	2,21	2,16	2,10	2,04	1,86	1,76	1,67	1,41	1,11	0,80	0,56	-0,9	-0,5	-1,2	-1,1	-4,0	-6,7
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8,57	7,97	7,92	8,07	7,39	7,25	6,09	5,40	4,77	3,83	2,87	1,90	1,23	-0,8	-0,7	-1,9	-2,4	-4,9	-8,1
CO2 Emissions to GDP (t of CO2/MEuro'05)	495,0	434,4	377,0	356,7	324,0	288,9	221,1	180,4	147,5	109,8	76,6	47,0	28,1	-2,7	-1,5	-3,7	-4,0	-6,3	-9,5
Import Dependency %	44,6	43,5	46,8	52,5	53,8	56,5	55,0	55,6	57,5	56,5	53,1	49,4	45,1						
Energy intensity indicators (2000=100)																			
Industry (Energy on Value added)	130,3	115,2	100,0	95,1	89,8	84,5	75,6	68,8	63,7	58,0	53,8	47,2	41,9	-2,6	-1,1	-1,7	-1,7	-1,7	-2,5
Residential (Energy on Private Income)	114,4	113,2	100,0	97,5	96,3	89,7	73,3	63,2	56,6	49,4	43,1	36,3	29,7	-1,3	-0,4	-2,7	-2,6	-2,7	-3,7
Tertiary (Energy on Value added)	126,5	117,0	100,0	99,4	93,9	88,0	72,0	59,3	51,4	44,6	38,6	32,6	27,1	-2,3	-0,6	-2,6	-3,3	-2,8	-3,5
Transport (Energy on GDP)	102,5	102,3	100,0	97,6	96,8	90,4	78,0	68,6	61,4	52,6	43,1	36,2	30,8	-0,2	-0,3	-2,1	-2,4	-3,5	-3,3
Carbon Intensity indicators																			
Electricity and Steam production (t of CO_2/MWh)	0,46	0,40	0,37	0,35	0,31	0,27	0,21	0,17	0,13	0,09	0,05	0,02	0,00	-2,1	-2,0	-3,8	-4,5	-9,2	
Final energy demand (t of CO_2/toe)	2,24	2,16	2,08	2,03	1,94	1,86	1,75	1,67	1,63	1,45	1,21	0,97	0,74	-0,7	-0,7	-1,1	-0,7	-2,9	-4,8
Industry	2,14	2,06	1,91	1,78	1,60	1,49	1,38	1,31	1,29	1,14	1,01	0,82	0,61	-1,1	-1,7	-1,5	-0,7	-2,4	-4,9
Residential	1,89	1,72	1,63	1,58	1,52	1,45	1,32	1,19	1,17	1,03	0,84	0,63	0,38	-1,5	-0,6	-1,4	-1,2	-3,3	-7,5
Tertiary	1,90	1,72	1,51	1,48	1,42	1,30	1,12	1,07	1,07	0,99	0,81	0,60	0,37	-2,2	-0,7	-2,3	-0,4	-2,8	-7,5
Transport	2,90	2,90	2,91	2,91	2,83	2,78	2,68	2,62	2,53	2,26	1,93	1,59	1,35	0,0	-0,3	-0,6	-0,6	-2,7	-3,5
Electricity and steam generation																			
Net Generation Capacity in MW_e			**654168**	**715466**	**821498**	**926071**	**1028502**	**1075129**	**1198871**	**1305721**	**1493474**	**1630142**	**1721011**		**2,3**	**2,3**	**1,5**	**2,2**	**1,4**
Nuclear energy			133966	134452	131393	125743	123641	96195	62110	38502	30675	19846	15501		-0,2	-0,6	-6,7	-6,8	-6,6
Renewable energy			112878	147262	206776	283787	419250	505806	672162	784712	945955	1069262	1192680		6,2	7,3	4,8	3,5	2,3
Hydro (pumping excluded)			99714	104505	107315	111540	114859	116960	119176	121256	122464	124554	126859		0,7	0,7	0,4	0,3	0,4
Wind			12793	40584	83905	143654	246396	303989	411622	473458	554340	612137	674115		20,7	11,4	5,3	3,0	2,0
Solar			371	2172	15307	28018	56262	81851	137038	183893	261900	323804	380723		45,1	13,9	9,3	6,7	3,8
Other renewables (tidal etc.)			0	1	249	575	1732	3005	4327	6105	7252	8767	10982			21,4	9,6	5,3	4,2
Thermal power			407324	433752	483329	516541	485612	473129	464599	482506	516844	541034	512830		1,7	0,0	-0,4	1,1	-0,1
of which cogeneration units			76247	85453	98311	119406	125133	135436	149703	163897	164135	169283	170040		2,6	2,4	1,8	0,9	0,4
of which CCS units			0	0	0	0	2711	2711	8209	61535	129400	213141	247835				11,7	31,8	6,7
Solids fired			194165	186620	183620	182825	154527	131745	115037	122760	128280	125565	124868		-0,6	-1,7	-2,9	1,1	-0,3
Gas fired			129444	166863	218514	242623	233617	236189	236679	240491	261180	285925	255451		5,4	0,7	0,1	1,0	-0,2
Oil fired			71058	62082	55901	46087	34821	32248	29516	28203	24752	18766	17720		-2,4	-4,6	-1,6	-1,7	-3,3
Biomass-waste fired			12051	17502	24567	44098	61483	71646	81332	88881	100373	108425	112395		7,4	9,6	2,8	2,1	1,1
Hydrogen plants			0	0	0	0	0	0	0	0	0	0	0						
Geothermal heat			605	686	727	908	1164	1302	2035	2172	2259	2354	2395		1,9	4,8	5,8	1,0	0,6
Load factor for net electric capacities (%)			49,1	49,1	43,9	42,6	39,3	38,3	33,9	33,2	32,5	30,9	30,0						
Indicators for gross electricity production																			
Efficiency for thermal electricity production (%)			37,6	38,5	39,5	40,0	39,8	40,8	40,6	43,0	45,3	47,1	47,3						
CHP indicator (% of electricity from CHP)			11,4	11,7	14,9	19,0	20,3	21,7	22,4	22,2	20,3	19,9	18,1						
CCS indicator (% of electricity from CCS)			0,0	0,0	0,0	0,0	0,5	0,7	2,1	12,8	22,2	30,4	31,9						
Non fossil fuels in electricity generation (%)			45,8	44,8	47,2	50,7	60,3	63,6	68,0	64,9	64,4	65,3	67,3						
- nuclear			31,6	30,5	27,5	25,4	24,0	20,8	13,4	7,8	5,5	3,2	2,5						
- renewable energy forms and industrial waste			14,2	14,3	19,7	25,3	36,4	42,8	54,6	57,1	58,8	62,1	64,8						
Indicators for renewables (excluding industrial waste) (%) (B)																			
RES in gross final energy demand (%)			7,6	8,6	11,4	14,8	21,2	24,5	28,8	34,3	41,3	49,7	57,5						
RES in transport (%)			0,5	1,4	4,3	6,6	10,9	13,9	19,1	30,9	44,6	55,8	64,2						
Transport sector																			
Passenger transport activity (Gpkm)	**4880,7**	**5307,7**	**5892,2**	**6240,3**	**6511,3**	**7132,2**	**7480,2**	**7908,5**	**8340,8**	**8638,2**	**8897,8**	**9145,0**	**9321,6**	**1,9**	**1,0**	**1,4**	**1,1**	**0,6**	**0,5**
Public road transport	544,0	504,0	517,6	526,0	545,0	573,7	639,6	675,1	721,6	767,7	807,3	847,3	890,0	-0,5	0,5	1,6	1,2	1,1	1,0
Private cars and motorcycles	3501,1	3986,3	4428,1	4686,5	4866,0	5288,2	5414,2	5644,5	5875,4	5992,2	6097,9	6172,9	6203,9	2,4	0,9	1,1	0,8	0,4	0,2
Rail	472,5	421,7	447,9	461,0	482,5	525,1	607,1	644,5	701,2	759,1	813,6	885,0	964,8	-0,5	0,7	2,3	1,5	1,5	1,7
Aviation	317,3	351,3	456,9	527,3	576,9	702,8	776,2	899,4	995,2	1069,7	1127,6	1186,6	1208,4	3,7	2,4	3,0	2,5	1,3	0,7
Inland navigation	45,8	44,4	41,7	39,5	40,8	42,5	43,1	45,0	47,4	49,5	51,5	53,1	54,5	-0,9	-0,2	0,6	0,9	0,8	0,6
Travel per person (km per capita)	10376	11127	12248	12756	13038	14047	14557	15273	16042	16591	17108	17642	18090	1,7	0,6	1,1	1,0	0,6	0,6
Freight transport activity (Gtkm)	**1848,4**	**1942,4**	**2195,7**	**2494,6**	**2662,6**	**2952,3**	**3058,2**	**3209,7**	**3365,7**	**3475,9**	**3590,6**	**3645,4**	**3636,4**	**1,7**	**1,9**	**1,4**	**1,0**	**0,6**	**0,1**
Trucks	1060,4	1288,7	1518,7	1800,3	1940,3	2164,3	2155,1	2252,5	2340,6	2377,1	2419,5	2405,9	2330,1	3,7	2,5	1,1	0,8	0,3	-0,4
Rail	526,3	386,1	403,7	414,1	440,5	489,0	575,3	608,0	657,2	711,2	767,4	821,0	876,3	-2,6	0,9	2,7	1,3	1,6	1,3
Inland navigation	261,6	267,6	273,3	280,2	281,9	299,0	327,8	349,1	367,9	387,7	403,7	418,5	430,0	0,4	0,3	1,5	1,2	0,9	0,6
Freight activity per unit of GDP (tkm/000 Euro'05)	227	222	217	225	234	232	216	207	200	191	184	174	161	-0,4	0,7	-0,8	-0,8	-0,8	-1,3
Energy demand in transport (ktoe)	**280269**	**300617**	**339389**	**362405**	**369964**	**387148**	**370834**	**356978**	**346607**	**320820**	**282583**	**255101**	**233542**	**1,9**	**0,9**	**0,0**	**-0,7**	**-2,0**	**-1,9**
Public road transport	5197	4732	4914	5039	5182	5315	5422	5236	4925	4637	3789	3404	3320	-0,6	0,5	0,5	-1,0	-2,6	-1,3
Private cars and motorcycles	154395	166321	182974	187736	186407	184711	167383	148571	139304	122019	96088	83957	73503	1,7	0,2	-1,1	-1,8	-3,6	-2,6
Trucks	74969	79037	90951	105104	111606	123126	119058	121370	121625	114475	105852	93858	84726	2,0	2,1	0,6	0,2	-1,4	-2,2
Rail	9560	9452	9600	9436	9594	10157	11032	10594	9617	9386	9087	8656	8299	0,0	0,0	1,4	-1,4	-0,6	-0,9
Aviation	29038	34112	45395	49703	51709	58141	61868	64820	64430	63407	60777	58327	56916	4,6	1,3	1,8	0,4	-0,6	-0,7
Inland navigation	7110	6963	5555	5386	5466	5699	6070	6386	6706	6895	6990	6899	6778	-2,4	-0,2	1,1	1,0	0,4	-0,3
Efficiency indicator (activity related)																			
Passenger transport (toe/Mpkm)	39,6	39,5	40,3	39,5	38,0	35,4	31,9	28,2	25,5	22,5	18,5	16,4	14,8	0,2	-0,6	-1,7	-2,2	-3,2	-2,2
Freight transport (toe/Mtkm)	47,1	46,8	46,3	46,5	46,0	45,7	43,2	41,8	39,7	36,4	32,8	28,9	26,3	-0,2	-0,1	-0,6	-0,8	-1,9	-2,2

ATTACHMENT 2: ASSUMPTIONS ABOUT INTERCONNECTIONS AND MODELLING OF ELECTRICITY TRADE

Short description of the model

The electricity trade model of PRIMES covers all countries in the European continent except countries of the CIS and Turkey. Interconnector capacities at the various country borders are determined exogenously.

The model performs unit commitment, endogenous use of interconnectors (with given capacities and Net Transfer Capacities (NTC)) and also optimal power generation capacity expansion planning in a perfect foresight manner until 2050. Simulations of different electricity demand levels with the model allow identification of bottlenecks and of the amount of investment in interconnectors necessary to remove such bottlenecks.

The model covers demand both for electricity and CHP steam/heat, as given from results of the entire PRIMES model. Demand for electricity and for steam/heat is supposed to be given and is represented through two typical days (for winter and summer).

Investment in new power plants is endogenous. The rate of use of power capacities and interconnectors is endogenous. Regarding the use of interconnectors the model performs a linear Direct Current optimal power flow under oriented NTC constraints defined per each couple of countries. The model makes distinction between AC lines and DC lines, the use of the latter being controlled by operators. All interconnectors existing today or planned to be constructed in the future are represented (one by one) in the model.

Among the inputs, the model considers non linear cost-supply curves for fuels used in power generation and non linear investment cost curves for nuclear and renewable energy power plants, which are a function of total installed capacity (unit investment costs increase as approaching the potential).

The electricity model, used in stage 1, is identical to the model used in the entire PRIMES model, but could be used with endogenous electricity trade only for the work during stage 1 because of very long computing times for each model run when iterations are performed between demand and supply and for meeting carbon targets.

Assumptions for the modelling exercise

All data about NTCs and interconnection capacities were taken from ENTSOe databases. Information on new constructions was taken from the latest “Ten-year network development plan 2010-2020”, complemented, where necessary, with information from the Nordic Pool TSOs and the Energy Community (for South East Europe). Some of the planned new constructions would justify increase of NTCs values until 2020, as mentioned in the ENTSOe’s TYNDP document. Other mentioned new constructions regard directly the building of new interconnection lines which are introduced as such in the model database.
According to assumptions agreed with the Energy DG of the European Commission, the following three cases were formulated regarding the NTC values:

a) NTC-0: keeping the NTC values of 2020, which are much higher than today, unchanged until 2050; the projection of NTC values to the year 2020 from today levels follows a study by KEMA, except few cases either because the links were not included in that study or because ENTSOe's NTC values announced for 2010-2011 were exceeding the KEMA's values. This assumption does not use the TYNDP information about new constructions aiming at increasing the NTC values in the future, except indirectly if in some cases the KEMA values for 2020 increase from today's levels.

b) NTC-2: apply a doubling of 2020 NTC values between 2020 and 2050 and interpolate linearly between 2020 and 2050; increase capacities of interconnectors where necessary so as to keep NTC values lower than total interconnection capacity by individual couples of countries. Some additional DC lines were added (linking Italy with western Balkans).

c) NTC-4: apply a quadrupling of 2020 NTC values by 2050 and interpolate with extension of interconnection capacities where needed.

Two energy demand and pricing contexts were considered to analyze the implications from the above mentioned NTC assumptions, which are as follows:

1. Reference scenario: demand, prices, taxes and ETS carbon prices are taken as identical to the DG ENER Reference scenario. Some adjustments on electricity demand figures were made only for year 2010, based on monthly statistics for 2010, in order to be able to simulate the true NTC values for this year.
2. Decarbonisation scenario: demand, prices and ETS carbon prices, as well as the parameters mirroring RES facilitation and other policies, are taken from the DG CLIMA "Decarbonisation scenario under effective technologies and global climate action" scenario.

Discussion of model results for the Reference scenario with three NTC value cases

The model results show that the NTC values retained for the year 2020 do not lead to substantial changes compared to results for the standard Reference scenario, i.e. the Reference scenario referred to in the Low Carbon Economy Roadmap). The countries projected to be net exporters in the standard reference scenario remain so in the model results presented here; the same applies to countries projected to be net importers in the standard reference scenario. There are differences in the magnitude of exports or imports for the year 2020, as for example for Belgium, Portugal, Lithuania and Latvia (higher net imports), for Hungary and Denmark (lower net imports) and for Slovenia, Slovakia, Sweden and Bulgaria (more net exports). It is reminded that for the standard Reference scenario import-exports of electricity were derived following a different methodology, which applied common balancing by region, contrasting the pan-European balancing applied for the model runs presented here.
NTC-0 case.

Regarding the scenario with NTC values remaining unchanged at the year 2020, the model results provide information about congestion by considering whether the NTC constraints are binding or close to be binding for couples of countries. The findings from this analysis regarding the projected NTC values for 2020 are summarized below

- Link Switzerland-Germany: appears congested and NTC is 32% of capacity
- Link Germany-Poland: appears congested and NTC is 17% of capacity
- Link Denmark-Sweden: appears congested and NTC is 54% of capacity
- Link Austria-Italy: appears very congested and NTC is 16% of capacity
- Link Italy-Slovenia: appears congested and NTC is 15% of capacity

- Link Austria-Hungary: appears congested and NTC is 31% of capacity
- Link Slovenia-Croatia: appears congested and NTC is 18% of capacity
- Links in the Balkans (FYROM-Greece, Albania-Greece, Bulgaria-Greece, Serbia-FYROM, Romania-Serbia, Serbia-Albania, Bulgaria-FYROM) appear very congested and NTC are below 30% of capacity, except Greece-Bulgaria NTC which is 68% of capacity

Congestion is detected in the model runs due to NTCs that are only a small part of existing capacities. One option for dealing with congestion would be to increase NTC without necessarily construct new lines. From the above overview it can be seen that the congestions after 2020 remain between Germany and neighbours to the east and south, between Austria, Italy, Slovenia, and Hungary, and finally in the Balkans, both within the Balkans and the linkages with northern neighbours.

NTC-2 and NTC-4 cases

The NTC-2 and NTC-4 cases assume doubling and quadrupling of NTC values, respectively from 2020 to2050, with linear interpolation applied between 2020 and 2050. The model results show that this way of uniformly increasing the NTC values does not really solve the problem of systematic congestions mentioned above for the case NTC-0. These congestions are removed only in the case NTC-4 and after 2030, with the exception of the Austria-Italy and Germany-Poland links, which remain congested until 2050 despite the quadrupled NTCs. The congestion problems in the Balkans are removed only in the NTC-4 case after 2030, but the area remains strongly congested under the NTC-2 assumptions. The congestions in links with Germany (Switzerland, Poland, Czech Rep. and Austria) are not removed in the NTC-2 case.

The doubling and quadrupling of NTCs values do not provide any advantages concerning the large list of links, which are not found congested under the NTC-0 assumptions.

The doubling of NTCs under the assumptions of NTC-2 case lead to lower rates of use of interconnection capacities (reported as percentage of NTCs), compared with NTC-0 results in the following cases:

- UK-Ireland: 17 percentage points less use
- France, Belgium, Netherlands, Luxembourg, Germany: between 15 and 30 percentage points less use
- Nordic area: around 15 percentage points less use
- Czech Rep., Slovakia, Poland, Hungary, Romania, Croatia: between 20 and 30 percentage points less use
- Latvia-Estonia: 20 percentage points less use

Passing from the doubling to the quadrupling implies even lower rates of use of interconnection possibilities.

Both cases NTC-2 and NTC-4 have adverse implications on the rate of use of DC lines leading to lower rates of use compared to case NTC-0, which under NTC-4 are close to zero in some cases. The NTC constraints help using the DC links for which the NTC values are usually equal to the interconnection capacities. Excessively high NTC constraints, which also mean more AC links, imply much less use of DC lines, which of course is unrealistic, as the DC lines correspond to today known constructions and are furthermore expensive. So the companies would not build so many new AC lines as the ones corresponding to NTC-4 on economic grounds including the adverse effects on DC lines.

A major issue with NTC-2 and NTC-4 cases regards the investment cost implicitly associated with the increase of interconnection capacities stemming from the doubling and quadrupling of NTC values. Total interconnection capacity is projected to increase by 43% in 2020 compared to 2010 levels, as a result of implementing the construction program of the TYNDP. In NTC-0 the capacity remains roughly unchanged until 2050. But in NTC-2 the capacity has to increase by 95% in 2050 compared to 2020 levels and in NTC-4 this increase is 277%. Such a construction program exceeds by far capacity requirements and would unnecessarily penalize costs and electricity prices in the scenarios.

According to the model results, we obtain the following changes in energy terms from NTC-2 and NTC-4 assumptions compared to NTC-0 results:

- Total volume of electricity traded increases by 5% in NTC-2 and by 8% in NTC-4 compared to NTC-0 in cumulative terms for the period 2015-2050. It is evident that the additional cost of interconnectors cannot be justified by such small increases in total traded volumes (i.e. adding absolute values of flows between countries).
- Total electricity production costs decrease by 0.13% in NTC-2 and by 0.23% in NTC-4 compared to NTC-0 in cumulative terms 2015-2050
- CO_2 emissions from electricity production decrease by 0.8% in NTC-2 and by 0.9% in NTC-4 compared to NTC-0 in cumulative terms 2015-2050
- Nuclear and RES cumulative production are found slightly higher in NTC-2 and NTC-4 compared to NTC-0, but the changes are less than 1% in cumulative terms.

It can therefore be concluded that the NTC expansion according to the NTC-2 and NTC-4 assumptions are not needed for the functioning of the electricity system and would entail high unnecessary cost without providing any noticeable benefit. These assumptions do not solve the serious congestion issues, do not provide gains for the non congested areas and have adverse effects on the economics of DC lines.

The conclusion for a Reference or Current Policy Initiatives framework is therefore to follow an approach that focuses on identified bottlenecks. For stage 2 of the modelling it is appropriate to increase NTC values and interconnection capacities after 2020 in a selective way, with priority to areas that would be congested in the future according to the reference scenario results. Such areas are the southern and eastern connections of Germany, the area linking Italy, Austria and Slovenia, the linkages of Balkans with northern neighbours and the linkages within Balkans. Some NTC additions should be also made for the linkages Denmark-Sweden and Latvia-Estonia.

With lower electricity demand due to the assumed strong energy efficiency policies, these results also hold for the Current Policy Initiatives scenario.

Discussion of model results for a Decarbonisation scenario with three NTC value cases

Under the assumptions of the decarbonisation scenario, total demand for electricity (in the 32 countries included in the model) increases by 15% in 2050 compared to the Reference scenario for year 2050. ,
It is assumed that the renewable facilitation policies develop in all countries in favour of domestic renewable potential. The scenario does not assume inflows of RES electricity from outside EU countries (e.g. North Africa) and does not include the possibility of exploitation of offshore wind located at long distance from the coasts.

The results from the model show that the NTC values retained for the period until 2020 do not alter the electricity trade pattern projected in previous decarbonisation exercises and compared to the Reference scenario.

The congestions identified in the context of the decarbonisation scenario for the year 2020 are the same as in the context of the reference scenario (see previous section).

Under the assumptions of the NTC-0 case the results show congestions similar to those found for the reference scenario, i.e. in south and east of Germany, in the Balkans, in the northern connections of the Balkans, in the linkages between Italy, Austria and Slovenia. Some additional congestion cases, found in the context of decarbonisation, relate to the link Germany-Sweden, Norway-UK and Germany-UK which are based on DC-links and do not concern the NTC values.

The doubling of NTC values under the assumptions of the NTC-2 case does not help removing the congestions. The quadrupling of NTC values (NTC-4 case) helps removing the congestions only in the long term, after 2040. So the linear interpolation method seems not to be useful as it brings little benefits and entails high costs for building new interconnectors. Increase of NTC values in a selective way and at an early stage after 2020 seems more suitable.

In the context of the decarbonisation scenario, the NTC-2 case allows increase of total volumes traded by 12% when compared to NTC-0. The increase obtained for the NTC-4 case is 14% (up from NTC-0). NTC-2 reduces total power generation costs roughly by 0.85% in cumulative terms compared to NTC-0. In NTC-4, the additional effect on power generation costs is smaller, NTC-4 power generation costs are 0.2%) lower compared with NTC-2. It is important to note that these statements related to power generation costs, and that the move from NTC-0 to NTC-2 and even more NTC-4 involves large costs for grid investment. NTC-2 has small impacts favouring slightly more nuclear and RES generation, whereas NTC-4 add very little to NTC-2 effects.

Overall conclusions on decarbonisation scenarios (except for those with very strong reliance on RES)

Following these economic modelling results, the approach for further modelling was chosen to start fromNTC-0 assumptions and to increase in selective way NTC values immediately after 2020 for the linkages found to be congested. This concerns interconnections around Germany, in Austria-Italy-Slovenia, Balkans and Denmark-Sweden.

For very high RES penetration, such linkages may not be sufficient. Therefore, this case has been examined separately. The results of this analysis are reported in the following chapter.

Assumptions about interconnections in the Decarbonisation scenario with High RES deployment both domestically and in the North Sea

Under the assumptions of this decarbonisation scenario, full exploitation of off-shore wind potential at North Sea is foreseen. In this modelling, exploiting the highest possible offshore wind potential is envisaged for Denmark, the UK, France, Germany, Netherlands, Sweden, Norway, Belgium and Ireland, according to the division of the sea in economic zones. Data on potentials come from published reports (e.g. EEA); the additional potentials, compared to standard RES scenario, are remarkably high for Norway, UK and Netherlands. It is assumed that a dense DC interconnection system will develop mainly offshore but also partly onshore, to facilitate power flows from the North Sea offshore wind parks.

After several model runs with different DC topology configurations and after considering elimination of congestions arising from wind offshore power flows, we have concluded to the following assumptions about the additional DC interconnections:

In MW — Investment in additional new interconnectors in the 4.1 scenario – North Sea

		2030	2035	2040	2045	2050	Total
Ireland	UK	0	0	1000	0	0	1000
Spain	France	1000	0	1000	0	0	2000
France	Germany	0	0	1000	1000	0	2000
France	Belgium	0	0	1000	0	0	1000
Belgium	Netherlands	0	0	1000	1000	0	2000
Netherlands	Germany	0	500	1000	1000	0	2500
UK	France	1000	0	1000	500	0	2500
UK	Belgium	1000	0	500	0	0	1500
UK	Netherlands	0	0	1000	0	0	1000
UK	Germany	1000	0	1000	1000	0	3000
Norway	Belgium	1000	1000	1000	1000	1000	5000
Norway	Netherlands	1000	1000	500	500	0	3000
Norway	Germany	1000	1000	1000	1000	1000	5000
Germany	Denmark	0	1000	2000	1000	500	4500
Norway	Denmark	1000	0	0	0	0	1000
UK	Norway	0	1000	0	1000	0	2000
Norway	Sweden	1000	0	0	0	0	1000
Sweden	Poland	1000	2000	2000	2000	3000	10000
Netherlands	Denmark	500	500	1000	500	0	2500
Denmark	Sweden	500	500	1000	1000	1000	4000
Germany	Poland	0	1000	1000	1500	1500	5000
Denmark	Poland	0	1000	2000	2500	500	6000
	Total	11000	10500	21000	16500	8500	67500

The NTC values are identical to the DC capacities, as assumed for all DC lines.

The congestions in this scenario are related to the wheeling of electricity from the North Sea region to consumption centres. The links of Sweden with Poland, Sweden with Lithuania, Austria with Italy, France with Italy and links in the Balkan region appear to be congested.
In this scenario, the electricity trade changes drastically. The United Kingdom, Netherlands, Denmark, Sweden, Norway export large amount of electricity while France, Belgium Germany, Italy, Czech Republic, Slovakia, Poland become or remain importing countries. This changes the results for the decarbonisation scenario as regards several countries.

ATTACHMENT 3: SHORT DESCRIPTION OF THE MODELS USED

The scenarios were derived with the PRIMES model by a consortium led by the National Technical University of Athens (E3MLab), supported by some more specialised models (e.g. GEM-E3 model that has been used for projections for the value added by branch of activity and PROMETHEUS model that has been deployed for projections of world energy prices).

GEM-E3

The GEM-E3 (World and Europe) model is an applied general equilibrium model, simultaneously representing World regions and European countries, linked through endogenous bilateral trade flows and environmental flows. The European model is including the EU countries, the Accession Countries and Switzerland. The world model version includes 18 regions among which a grouping of European Union states. GEM-E3 aims at covering the interactions between the economy, the energy system and the environment. It is a comprehensive model of the economy, the productive sectors, consumption, price formation of commodities, labour and capital, investment and dynamic growth. The model is dynamic, recursive over time, driven by accumulation of capital and equipment. Technology progress is explicitly represented in the production function, either exogenous or endogenous, depending on R&D expenditure by private and public sector and taking into account spillovers effects. The current GEM-E3 version has been updated to the GTAP7 database (base year 2004) and has been updated with the latest Eurostat statistics for the EU Member States.

PRIMES model

The PRIMES model simulates the response of energy consumers and the energy supply systems to different pathways of economic development and exogenous constraints and drivers. It is a modelling system that simulates a market equilibrium solution in the European Union and its member states. The model determines the equilibrium by finding the prices of each energy form such that the quantity producers find best to supply match the quantity consumers wish to use. The equilibrium is forwarding looking and includes dynamic relationships for capital accumulation and technology vintages. The model is behavioural formulating agents' decisions according to microeconomic theory, but it also represents in an explicit and detailed way the available energy demand and supply technologies and pollution abatement technologies. The system reflects considerations about market competition economics, industry structure, energy /environmental policies and regulation. These are conceived so as to influence market behaviour of energy system agents. The modular structure of PRIMES reflects a distribution of decision making among agents that decide individually about their supply, demand, combined supply and demand, and prices. Then the market integrating part of PRIMES simulates market clearing.

PRIMES is a partial equilibrium model simulating the entire energy system both in demand and in supply; it contains a mixed representations of bottom-up and top-down elements. The PRIMES model covers the 27 EU Member States as well as candidate and neighbour states (Norway, Switzerland, Turkey, South East Europe). The timeframe of the model is 2000 to 2050 by five-year periods; the years up to 2005 are calibrated to Eurostat data. The level of detail of the model is large as it contains:

- 12 industrial sectors, subdivided into 26 sub-sectors using energy in 12 generic processes (e.g. air compression, furnaces)
- 5 tertiary sectors, using energy in 6 processes (e.g. air conditioning, office equipment)
- 4 dwelling types using energy in 5 processes (e.g. water heating, cooking) and 12 types of electrical durable goods (e.g. refrigerator, washing machine, television)
- 4 transport modes, 10 transport means (e.g. cars, buses, motorcycles, trucks, airplanes) and 10 vehicle technologies (e.g. internal combustion engine, hybrid cars)
- 14 fossil fuel types, new fuel carriers (hydrogen, biofuels) 10 renewable energy types
- Main Supply System: power and steam generation with 150 power and steam technologies and 240 grid interconnections
- Other sub-systems: refineries, gas supply, biomass supply, hydrogen supply, primary energy production
- 7 types of emissions from energy processing (e.g. SO2, NOx, PM)
- CO2 emissions from industrial processes
- GHG emissions and abatement (using IIASA's marginal abatement cost curves for non CO2 GHGs).

For further information see http://www.e3mlab.ntua.gr/e3mlab/index.php?option=com_content&view=article&id=58%3Amanual-for-primes-model&catid=35%3Aprimes&Itemid=80&lang=en

Prometheus model

A fully stochastic World energy model used for assessing uncertainties and risks associated with the main energy aggregates including uncertainties associated with economic growth and resource endowment as well as the impact of policy actions (R&D on specific technologies, taxes, standards, subsidies and other supports). The model projects endogenously to the future the world energy prices, supply, demand and emissions for 10 World regions. World fossil fuel price trajectories are used for the EU modelling as import price assumptions for PRIMES.

Annex 2 - Energy Roadmap 2050 – Selected Stakeholders' Scenarios

1. INTRODUCTION

Stakeholders are continuing their work on scenarios for long term transformation of energy systems. These analyses, using a variety of models and assumptions and exploring a variety of constraints, all help in assessing the **robustness of conclusions** on policy actions needed in the coming years.

The bulk of this report, chapters 2-4, is a systematic presentation of a representative sample of European long term energy scenarios. Their policy targets, assumptions on various economic, social and technological factors, and resulting outcomes of model-based analyses are compared. The purpose is not to judge the outcomes of the scenarios but to try to understand and clearly describe the similarities and differences in the scenarios[20]. This work was completed in April 2011.

Since then, several scenarios this year explore consequences of the Fukushima accident and unconventional gas. In the **IEA**[21]'s global scenario to 2035 entitled The Golden Age of Gas, ample availability of gas, much of it unconventional, keeps average gas prices well below levels assumed in WEO-2010. Especially in growing economies in China and other non-OECD countries, gas consumption increases throughout the energy system, driven by price, improved access to supplies, efficiency improvements in technologies, also emissions benefits. Its flexibility is a distinct benefit in a perspective of much change in energy systems and much uncertainty about how drivers will play out. In Europe, scenario analyses by the **European Gas Advocacy Forum**[22] and **Eurogas**[23] underline this flexibility and how it can be used. EGAF argues that with greater use of gas in the short to medium term, to 2030 or so, implementation risks in the early years of a long-term strategy focused on renewables[24] can be reduced as well as overall costs. Eurogas similarly argues that the balance which will emerge between renewables and CCS/fossil fuels cannot be known today and that investing in gas keeps these long-term options open. The importance of **CCS** in these strategies in the long term is evident in the IEA scenario which does not assume availability of CCS by 2035. In this scenario, the long-term trajectory for CO2 emissions is towards 650ppm, thus a probable temperature rise well above the 2 degrees C target.

The European Climate Foundation in this year's phase of its Roadmap 2050 work, concentrates on trade-offs in the **period till 2030**, exploring coherent policy actions needed to keep the European energy system on track to 2050. With further analyses of its 60% renewables and high renewables scenarios for the power sector[25], trade-offs among additional grid infrastructures, generation capacities and their location, storage and demand side management are examined. Additional grid investments beyond 2020, although substantial, are low compared to generation investments. If these grid investments are not made, the result

[20] Key references for this work are: (1) "Analysis and Comparison of Relevant Mid- and Long-term Energy Scenarios for EU and their Key Underlying Assumptions" (PROGNOS, 2011) [8], and (2) "Key Factors Affecting the Deployment of Electricity Generation Technologies in Energy Technology Scenarios" (Paul Scherrer Institut, 2009) [9].

[21] World Energy Outlook 2011 - special early insights: "Are We Entering A Golden Age Of Gas?" International Energy Agency, June 2011 (complete WEO 2011 due 9 November)

[22] "Making the Green Journey Work", European Gas Advocacy Forum, February 2011

[23] Eurogas Roadmap 2050, 13 October 2011

[24] EGAF refers to European Climate Foundation's 60% RES scenario for the power sector (Roadmap 2050, 2010)

[25] "Power Perspectives 2030", European Climate Foundation, 7 November 2011; scenarios from Roadmap 2050, ECF, 2010.

is an increase in back-up and operational costs amounting to far more than the grid investments saved. Demand response, within day, reduces the need for additional transmission infrastructure. The deployment of renewables in order of productiveness across Europe reduces cumulative generation capital costs by over a fifth by 2030 compared to a Member State by Member State approach. ECF also examines price setting in regional markets and utilisation rates of additional back-up plant, crucial for understanding market design issues.

Greenpeace concentrated on grids in its 2011 scenario analyses[26], building on its earlier Renewables 24/7 study. Looking beyond 2030, a High Grid scenario encompassing much trade and North African solar resources and a Low Grid scenario with more local solutions within Europe are explored. With adequate transmission, both would imply shrinking utilisation rates for coal and nuclear plants and later for gas fired plants, which could then be converted to biogas.

Scenarios for sustained transformation of the energy system are now being developed by a **whole range of organisations**, at local, Member State and European level[27]. Many look explicitly at the European market and policy context[28].

The conclusions of these scenario analyses and the **analyses by the Commission** are consistent on many but not all issues. All agree on the importance of **energy efficiency** in any strategy. The increased reliance on **capital investments** in the transformation of the energy system and in energy efficiency improvements is evident in all scenarios, raising financing, risk management and cost of capital issues to the top of the agenda. All see a much stronger reliance on **renewables** than currently, which raises issues notably for the power system. **Flexibility** from all sources is increasingly important. **Grid investments** and the market developments that go with them look like a no-regrets policy, at least in the period to 2030. Areas of difference among scenarios often concern **timing**. They include the degree of **early reliance on electrification** as opposed to direct use of, notably, gas, in heating, transport and industry. Estimates of **total system costs** in scenarios are still very different. They are not easy to compare.

2. SCANNING OF STAKEHOLDER SCENARIOS

A variety of international organisations, industry associations, individual companies, NGOs and research/academic institutions have put forward mid- and long-term energy scenarios. In order to make a representative sample, 28 studies were identified by screening contributions and publications from stakeholders.

A representative set of 7 studies was selected (see Table 1). The criteria used were time horizon until at least 2030, geographical coverage of EU-27 (or Europe[29]), public availability of main results in a quantitative form, coverage of at least the electricity sector, level of detail, and the scenarios being well known and discussed internationally. For example, studies covering only the world as a whole without defining Europe as a region were not selected. The time horizon, geographical and sectorial coverages, as well as the level of detail, vary greatly among the scanned studies.

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26 "Battle of the Grids", Greenpeace supported by Energynautics, 2011

27 For example, members of European Environment and Sustainable Development Advisory Councils

28 Eg. DIW work for review of German energy concept

29 "Europe" is sometimes defined as OECD-Europe, EU-25 (for older scenario studies) or EU-27.

Table 1: Scanning of Energy Scenario Studies

Nr.		Year of publication	Time horizon	Amount of scenarios (sensitivities)	Geographical coverage: World	Europe	EU-27	Quantifiability	Coverage of the sectors: Residential	Commercial / Services	Industrial	Transportation	Power	Other conversion sectors	Amount of sectors covered	Level of detail (our subjective estimate)	Type of model: Bottom-up	Top-down	None	Short list for selection
	Governmental institutions:																			
1	US-DOE EIA (2010). International Energy Outlook 2010	2010	2035	1 (+4)	x	*(OECD)*	*(EU-19)*	x	x	x	x	x	x	x	6	+++	x			
2	European Parliament (2009). Future Energy Systems in Europe	2009	2030	3			x	x		x		x	x		3	+	x			
3	EU DG TREN/ENER (2008, 2010, 2011) - "EC Reference Scenario to 2050"	2008 / 2010	2030	1 resp. 2			x	x	x	x	x	x	x	x	6	+++	x			x
4	EU DG Research (2006). World Energy Technology Outlook. WETO - H2	2006	2050	3	x	x		x	x		x	x	x		4	++	x			
5	EU DG TREN (2006). Scenarios on energy efficiency and renewables	2006	2030	3 (+2)			*(EU-25)*	x	x	x	x	x	x	x	6	++	x			
	Inter-governmental institutions and Non-governmental organisations:																			
6	ECF (2010). Roadmap 2050	2010	2050	3 (+1)			x		x	x	x	x	x	?	6	+++	x			x
7	EREC (2010). RE-Thinking 2050	2010	2050	1 (+1)			x	x	x (Renewable heat)				x (RES-E)		2	+	x			(x)
8	Greenpeace/EREC (2010). Energy [r]evolution	2010	2050	3	x	*(OECD)*	x	x	x		x	x	x		4	+++	x			x
9	IEA (2010). Energy Technology Perspectives	2010	2050	2 (+4)	x	x	x	x	x		x	x	x	x	5	+++	x			x
10	IEA/NEA (2010). Technology Roadmap; Nuclear Energy	2010	2050	3	Based on IEA (2010)				Based on IEA (2010)						0	+				
11	IAEA (2009). Energy, Electricity and Nuclear Power Estimates for Period up to 2030	2009	2030	2	x	x		x					*(Nuclear)*		0	+				
12	IEA (2009). World Energy Outlook 2009	2009	2030	2	x	*(OECD)*	x	x	x		x	x	x	x	5	+++	x			x
13	NEA (2008). Nuclear Energy Outlook 2008	2008	2050	2	x	*(OECD)*							*(Nuclear)*		0	+			x	
14	WEC (2007). Deciding the Future: Energy Policy Scenarios to 2050	2007	2050	4	x			*(x)*							0	+				
15	EEA (2005). European Environment Outlook	2005	2030	2		x	x		x	x	x	x	x		5	+	x			
	Industry:																			
16	ExxonMobil (2009). Outlook for Energy; A View to 2030	2009	2030	1	x			x	x		x	x	x		4	+	x (?)			
17	IHS Global Insight (2008). European Energy and Environmental Outlook	2008	2030	1		x	x	x	x	x	x	x	x	x	6	++	x (?)			
18	Shell (2008). Shell energy scenarios to 2050	2008	2050	2	x			x	x	x	x	x			4	+	x (?)			
19	PWC (2006). The World in 2050	2006	2050	6	x			x							0	+	x (?)			
	Industry associations:																			
20	Eurelectric (2009). Power Choices	2009	2050	1 (+ base)			x	x	x	x	x	x	x		5	++	x			x
21	Euracoal (2007). The future role of coal in Europe	2007	2030	5			x	x					x		1	++	x			
22	Eurelectric (2007). The Role of Electricity	2007	2030/2050	4			*(EU-25)*	x	x	x	x	x	x		5	+	x			
	Research / academic consortia:																			
23	FEEM et al.(2010). Probabilistic long-term assessm.of new energy technol.scenarios	2010	2050	10	x	x	x	x	x	x	x	x	x	x	6	+++	x	x		x
24	Capros et al. (2008). Model-based Analysis of the 2008 EU Policy Package	2008	2030	9			x	x	x	x	x	x	x	x	6	++	x			
25	Energy Watch Group (2008). Renewable Energy Outlook 2030	2008	2030	2	x	*(OECD)*		x		x		x	x	x	4	++	x			
26	Öko-Institut (2006, update 2011). The Vision Scenario for the European Union	2006	2030	2			*(EU-25)*	x	x	x	x	x	x	x	6	+	x			
27	ECN (2005). The next 50 years: Four European energy futures	2005	2050	4		x									0	+			x	
28	ISIS et al. (2005-9). NEEDS - New Energy Externalities Development for Sustainability	2009	2050	7		x		x								+				

The **7 studies selected to be compared in detail** are, as follows (see full references at the end of this report):

- ***European Commission Reference Scenario to 2050***, published in 2011, [1]:
  - *"The 2050 Reference scenario depicts energy and greenhouse gas (GHG) emission developments on the basis of policies implemented up to March 2010, mirroring as well the achievement of the legally binding 2020 targets on renewables (RES) and GHG and the implementation of the ETS Directive. It shows the magnitude of the additional effort needed for EU policies to achieve the European Council's GHG mitigation objective."*

- ***European Climate Foundation (ECF) – Roadmap 2050***, 2010, [2]:
  - *"The objectives of the Roadmap 2050 are: a) to investigate the technical and economic feasibility of achieving at least an 80% reduction in greenhouse gas emissions below 1990 levels by 2050, while maintaining or improving today's levels of electricity supply reliability, energy security, economic growth and prosperity; and b) to derive the implications for the European energy system over the next 5 to 10 years."*

- ***Greenpeace/EREC – Energy [R]evolution (+EREC (2010), Re-thinking 2050)***, 2010, [3]:
  - *"The report demonstrates how the world can get from where we are now, to where we need to be in terms of phasing out fossil fuels, cutting CO2 while ensuring energy security. This includes illustrating how the world's carbon emissions from the energy and transport sectors alone can peak by 2015 and be cut by over 80% by 2050."*

- ***International Energy Agency (IEA) – Energy Technologies Perspectives (ETP)***, 2010, [4]:
  - *"The goal of the analysis in this book is to provide an IEA perspective on the potential for energy technologies to contribute to deep emission reduction targets and the associated costs and benefits. It uses a techno-economic approach to identify the role of both current and new technologies in reducing CO2 emissions and improving energy security."*

- ***IEA – World Energy Outlook (WEO)***, 2009, [5]:
  - *"The results of the analysis presented here aim to provide policy makers, investors and energy consumers alike with a rigorous, quantitative framework for assessing likely future trends in energy markets and the cost-effectiveness of new policies to tackle climate change, energy insecurity and other pressing energy-related policy challenges."* (Reference scenario);
  - *"More specifically, this report is intended to inform the climate negotiations by providing an analytical basis for the adoption and implementation of commitments and plans to reduce greenhouse-gas emissions."* (450 Scenario).

- ***Eurelectric – Power Choices***, 2009, [6]:
  - *"The Eurelectric Power Choices study was set up to examine how the vision, of cutting Greenhouse Gas (GHG) emissions by 75% in 2050, can be made reality. Power Choices looks into the technological developments that will be needed in the coming decades and examines some of the policy options that will have to be put in place within the EU to attain a deep cut in carbon emissions by mid-century."*

- ***FEEM[30] et al., EU-RTD Project PLANETS: Probabilistic Long-term Assessment of New Energy Technology Scenarios***, 2010, [7]:
  - *"PLANETS is a research project funded by the EC under the 7th Framework Programme with the scope of devising robust scenarios for the evolution of energy technologies in the next 50 years. The project aims to assess the impact of technology development and deployment at world and European levels, by means of an ensemble of analytical tools designed to foresee the best technological hedging policy in response to future environmental and energy policies."*

[30] Fondazione Eni Enrico Mattei (FEEM).

3. COMPARATIVE ANALYSIS OF SCENARIO STUDIES

3.1 Policy Assumptions and Targets

All scenario studies analysed use a *"baseline scenario"* to show the impact of presently implemented policies (e.g. until 2009). These baseline scenarios are used as a basis for assessing impacts of alternative scenarios.

The *"alternative scenarios"* all aim at reducing GHG or CO_2 emissions (and are generally in line with the EU 2020 target of -20% and to the long term target of -80% to -95% by 2050).

Most models concentrate on the electricity sector and are much less detailed (or provide no details) on developments in the heating and transport sectors (except insofar as they may assume major electrification in these sectors).

Table 2 gives an overview of main pre-defined policy assumptions and targets across the scenarios (for EU-27 or OECD-Europe, depending on study) for:

- GHG or CO_2 emissions reduction (economy-wide),
- Share of renewables (RES),
- Role of nuclear,
- Efficiency,
- Emission Trading System (ETS) and remarks on status of policies taken into account.

Table 2: Overview of Main Policy Assumptions and Pre-Defined Targets in the Scenarios

Short name scenario	GHG or CO_2-emissions reduction, economy-wide	Share of renewables in gross final energy consumption	Share of nuclear in power generation	Reduction in primary energy by improved energy efficiency	Carbon policy
WEO Ref	▪ GHG: -20% below 1990 levels by 2020 for EU	▪ 20% by 2020 for EU	▪	▪ 20% by 2020 for EU	▪ Policies until mid 2009 ▪ ETS
WEO 450 ppm	▪ GHG: -20% below 1990 levels by 2020 and -80% by 2050	▪ 20% by 2020	▪	▪ 20% by 2020	▪ Policies until mid-2009 ▪ ETS (OECD+, OME)
ETP BL OECD Europe	▪ GHG: -20% below 1990 levels by 2020 for EU	▪ 20% by 2020 for EU	▪	▪ 20% by 2020 for EU	▪ Policies until mid-2009 ▪ ETS
ETP Blue Map OECD Europe	▪ CO2eq: -74% below 2007 levels by 2050 ▪ GHG: -20% below 1990 levels by 2020 for EU	▪ 20% by 2020 for EU	▪	▪ 20% by 2020 for EU	▪ Policies until mid-2009 ▪ ETS (OECD+, OME)
EC Reference Scenario to 2050	▪ GHG: -20% below 1990 levels by 2020 (in Reference scenario)	▪ 20% by 2020 (in the Reference scenario)	▪ Economic modelling with currently non nuclear MS remaining non nuclear except Poland and Italy;	▪	▪ Implemented Policies until March 2010 & achievement of legally binding

			phase-out in 2 MS		targets ▪ Revised ETS Directive applied until 2050
ECF BL	▪ GHG: -20% below 1990 levels by 2020 for EU	▪ 20% by 2020 for EU	▪	▪ 20% by 2020 for EU	▪ Policies until mid-2009 ▪ ETS
ECF 80% RES	▪ GHG: -80% below 1990 levels by 2050	▪ 80% RES of power generation by 2050	▪ 10% nuclear of power generation by 2050	▪ 20% by 2020 for EU	▪ ETS (OECD+OME)
ECF 60% RES	▪ GHG: -80% below 1990 levels by 2050	▪ 60% RES of power generation by 2050	▪ 20% nuclear of power generation by 2050	▪ 20% by 2020 for EU	▪ ETS (OECD+OME)
ECF 40% RES	▪ GHG: -80% below 1990 levels by 2050	▪ 40% RES of power generation by 2050	▪ 30% nuclear of power generation by 2050	▪ 20% by 2020 for EU	▪ ETS (OECD+OME)
E[R] Ref	▪	▪	▪	▪	▪ No specific targets or policies mentioned
E[R]	▪ CO2: -80% below 1990 levels by 2050	▪	▪ Phasing out	▪	▪ No specific targets or policies mentioned
E[R] Adv	▪ CO2: -95% below 1990 levels by 2050	▪ High RES share: "Close to fully renewable energy system" by 2050	▪ Phasing out	▪	▪ No specific targets or policies mentioned
Eurelectric BL	▪	▪	▪ Germany and Belgium phased out	▪	▪ Policies until mid-2009 ▪ ETS
Eurelectric Power Choices	▪ GHG: -40% below 1990 levels by 2030 and -75% by 2050	▪ 20% by 2020	▪ Germany and Belgium phased out	▪ 20% by 2020 for EU	▪ Policies until mid-2009 ▪ ETS (all sectors)
FEEM-WITCH	▪	▪	▪ No exogenous constraint	▪	▪

Abbreviations used: ETS: Emissions Trading System, GHG: Greenhouse Gas, OME: Other Major Economies (Brazil, Russia, South Africa and the countries of the Middle East), MS: EU Member States.

From Table 2 it can be seen that:

In relation to reduction of GHG emissions,

- Most of the studies do not take into account negative or positive effects of climate change on the economy in the models used. One exception found are the FEEM-scenarios where the WITCH-model incorporates an integrated assessment module which is able to take into account a dynamic linkage of climate change and economic activity.

- In general, some form of European Emissions Trading (ETS) is considered in most studies (exceptions are Greenpeace/EREC and FEEM), some models used for scenarios development even have specific modules which simulate a market for emission allowances[31] (e.g. PRIMES used by both Commission services and Eurelectric).

- The scenarios differ in their assumptions about future emissions trading markets. There is a large consensus about the sectors included, but not about the geographical coverage. Some studies assume no extension of the current EU emissions trading, others assume an expansion of the market from OECD+ up to a global dimension. With the Clean Development Mechanism (CDM), another possibility to enlarge the geographic coverage of the allowances market exists. The EU DG ENER scenarios focus on this issue, other scenarios give little information. Finally, some scenarios envisage small deviations from the current status of the allocation process, assuming full auctioning in the power sector and grandfathering in the other sectors. Other scenarios tend towards a general full auctioning of allowances.

Carbon pricing in the different scenarios is shown in Table 3:

Table 3: Comparison of Carbon Pricing in the Scenarios

Scenario	**Sectoral coverage**	**Geographical coverage**	**Auctioning or grandfathering**	**CDM**
IEA – WEO	Existing EU-ETS, including aviation	n/a	n/a	CDM taken into account
IEA – WEO 450 ppm	n/a	OECD+ in 2013, major economies as of 2021	n/a	CDM taken into account
IEA – ETP Reference	n/a	n/a	n/a	n/a
IEA – ETP Blueline	n/a	n/a	n/a	n/a
EU DG ENER Reference	Existing EU-ETS including aviation	n/a	Auctioning in power sector, grandfathering for other-sectors	CDM taken into account
EU DG ENER Baseline	n/a	n/a	Auctioning in power sector, grandfathering for other-sectors	Limited use of CDM-credits
ECF Roadmap Reference	Industry, power sector, aviation	n/a	n/a	n/a
ECF Roadmap Pathways	Industry, power sector, aviation	Until 2020 OECD-countries, from 2020 including developing countries	n/a	n/a

[31] ETS is explicitly modelled by the Commission services' scenarios that derive ETS prices endogenously.

Energy [R]evolution	n/a	Global CO_2 trading system in the long term	n/a	n/a
Energy [R]evolution Advanced	n/a	Global CO_2 trading system in the long term	All allowances should be auctioned	n/a
Eurelectric Baseline	n/a	n/a	Full auctioning as of 2015 (except some new Member States)	n/a
Eurelectric Power Choices	ETS extended to all major economic sectors after 2020	International carbon market after 2020	Full auctioning as of 2015 (except some new Member States)	n/a
FEEM et al. - Planets	n/a	n/a	n/a	n/a

In relation to future energy mixes,

- A few studies use pre-defined future energy mix targets, by preferring or excluding certain technologies from the beginning (in a "back-casting approach"):
- Predetermined Role of Renewables (RES): Only Greenpeace/EREC and ECF make specifications on the desired shares of RES energies in 2050:
  - Greenpeace/EREC sets in its advanced Energy [R]evolution scenario the 2050 RES target share at 100% (all sectors).
  - ECF sets in its alternative scenarios the 2050 power sector RES target share at 40%, 60% and 80%, respectively.
- Predetermined Role of Nuclear Energy (NUC) and Carbon Capture & Storage (CCS): Greenpeace/EREC and ECF specify pre-defined shares of NUC and CCS in 2050:
  - Greenpeace/EREC sets in its advanced Energy [R]evolution scenario the 2050 NUC as well as CCS target shares to 0%.
  - ECF focuses on the RES share. For the purposes of the analysis, particularly of infrastructure needs, it divides the remaining share equally between NUC and CCS, thus 30%, 20% and 10% for each, in the three alternative scenarios[32].

The other scenarios determine the contribution of NUC and CCS on the basis of cost assumptions and optimisation rather than pre-defined policy targets.

In relation to sustainability aspects other than GHG reduction,

Economic constraints or the issue of maintaining high levels of grid stability and overall system reliability are in most cases either not considered or at least not fully quantified:

- Economic constraints, e.g.:
  - Minimisation of private financial costs (investment in new generation capacities and infrastructure (an exception is e.g. ECF)),
  - Minimisation of social costs, such as environmental externalities (costs of GHG avoided, other environmental pollution, land use, etc.)[33].

Maintaining high levels of grid stability and overall system reliability[34], e.g.:

[32] and 20% Demand-Side Management (DSM) by 2050 in the ECF study.

[33] In scenarios mirroring cost-effective achievement of GHG reduction, PRIMES scenarios make sure that marginal costs are equal across sectors and MS.

[34] In a study published by KEMA and Imperial College London in 2010 and performed for ECF, these issues went at least partly into the modelling.

The high relevance of this issue is due to the fact that scenarios with high shares of RES energy sources, particularly wind and solar energy, increase the need for backup capacity or other means of ensuring grid stability. Substitution of electricity for FOS fuels in buildings and transportation, results in higher electricity demand but also expanded possibilities for demand management. These challenges are addressed by all of the studies in one way or another. Several approaches can be identified in the scenarios:

- Flexible thermal power plants (NUC, FOS) for load-following operation and back-up capacity,
- Greater use of non variable RES energy (biomass, solar with storage, geothermal, hydro with pumped storage facilities),
- Transmission expansion. This approach is constrained in some of the scenarios by model limitations. In PRIMES, interconnections are exogenous. The model used in ECF's scenarios derives transmission needs,
- Large-scale storage
- Smart grids and demand side management developments.

Maintaining high levels of system reliability and thus high levels of power supply security is qualitatively mentioned across most studies as a key objective and in some studies also as a key challenge.

Regarding realisation, particularly studies with ambitious GHG reduction targets implicitly assume significant progress in grid technology (ECF maintains that they use existing technologies) and social acceptance related to transmission expansion to be able to achieve their targets. However, analysis is typically not taken further[35] from such largely qualitative statements and it is usually concluded that financing needs to be found for the large increases in pan-European transmission and storage capacities to be able to cope with the expected large future shares of intermittent generation.

Implications for distribution networks are not addressed by most of the studies. This is particularly concerning as almost all studies emphasize at the same time the relevance of technologically advanced smart grids and smart metering, especially those confronted with ambitious emission reductions (Energy [R]evolution, ECF Pathways, ETP Blueline, Eurelectric Power Choices).

In relation to security of supply of energy resources,

- All scenarios expect reserves of natural gas to be sufficient to meet future demands. Unconventional oil reserves are expected to be deployed in some scenarios without ambitious emission reductions (e.g. ETP Reference). No indictors of security of supply are developed. Possible indicators (diversity of imports, stability of exports, reliability of supply, diversity of supply, etc.) are not developed.

3.2 Economic Assumptions

Regarding general economic assumptions,

- The scenarios assume a steady increase of GDP of ~1-2% per year until 2030/2050. The recent financial crisis is taken into account in the projections of GDP.

[35] Only one study was identified containing specific data in this field (ECF/KEMA).

Regarding fossil fuel prices,

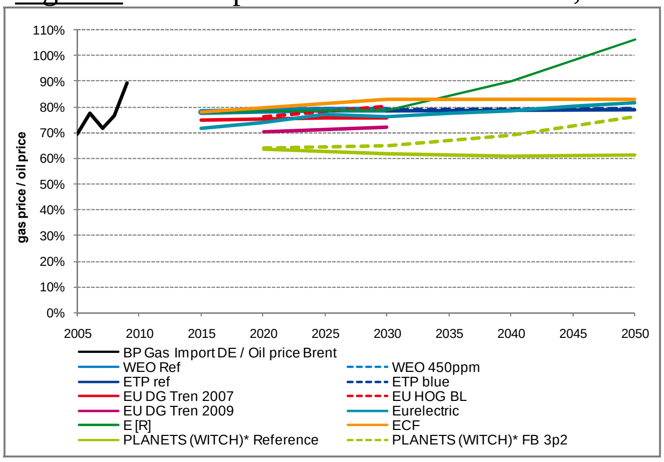
- Fossil fuel prices are often exogenously determined (in PRIMES scenarios by using a separate modelling framework). ECF and Greenpeace/EREC use price developments from WEO 2009. In WEO 2009, international fossil fuel prices are based on a top-down assessment of prices which would create enough investment to meet energy demand over the projection period (global balance of supply and demand). Therefore, fossil fuel prices in WEO are endogenously determined and sensitive to scenario assumptions. ETP takes prices up to 2030 from WEO 2009 and calculates prices for the period beyond 2030 by taking into account the long-term oil supply cost curve.

- Recent studies suggest a range of ~90-120 USD/barrel until 2030 and 2050 for the oil price. Only Greenpeace/EREC considers an oil price that increases to 150 USD/barrel in 2030. Oil prices in Greenpeace/EREC and ECF are assumed to stay constant after 2030.

- Until 2030 most scenarios presume an increasing gas price. In the IEA alternative scenarios the prices of gas, as for oil, stabilise or decrease after 2030 due to weaker energy demand, while in the reference case gas prices increase in respond to increasing demand (e.g. from additional gas-fired power plants).

- Most studies agree on the idea that gas prices will keep their linkage with oil prices, i.e. the ratio of gas and oil prices remains quite constant[36]. Main exceptions are the Greenpeace/EREC Energy [R]evolution and – to some extent – the alternative scenario of the PLANETS-WITCH project (see Figure 1). The PLANETS alternative scenario assumes a higher increase of gas prices than oil prices, motivated by the high gas demand and relatively low oil demand.

Figure 1: Development of Gas to Oil Prices, in %



[36] WEO expects US gas prices to be partly disconnected from oil prices, due to large indigenous gas reserves.

- A moderate increase of coal prices is assumed in most of the scenarios. Some differences exist in expectations of future gas-to-coal price ratios. Most of the studies (e.g. Eurelectric) expect coal prices to increase at far lower rates than gas prices. A slight decoupling can be observed in most of the scenario studies. In contrast to the other studies, the Energy [R]evolution of Greenpeace/EREC and the alternative scenario of the PLANETS-WITCH project show a stronger increase of coal than oil prices in the long run.

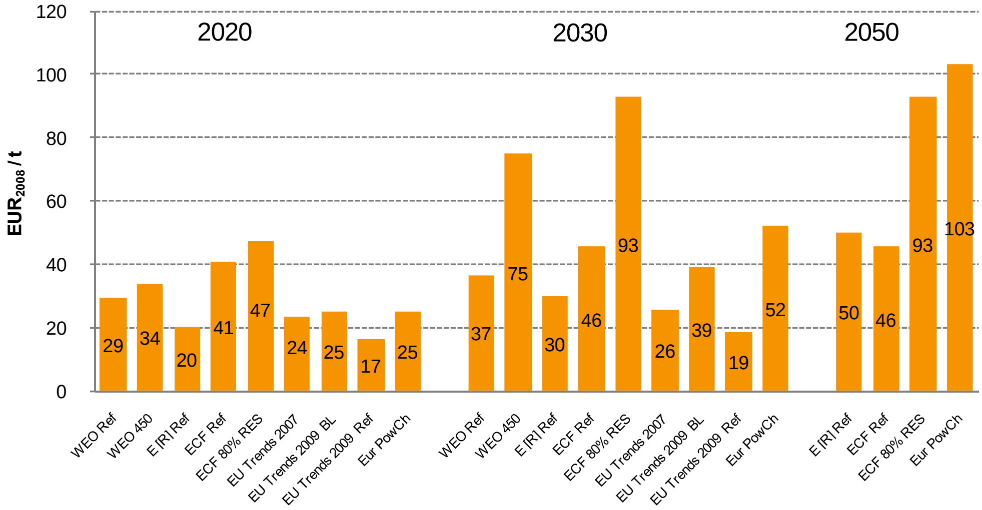
Regarding incentives for RES,

- Some studies (e.g. Eurelectric Power Choices) explicitly assume decreasing direct incentives for RES in the future due to assumed increasing cost-competitiveness.

Regarding CO2-certificate prices,

- Different developments for the (typically assumed) CO2-certificate prices are to some part also determined by targets set and the resulting CO2-emissions development. As shown in Figure 2, emissions in the ECF Pathways and the WEO 450 ppm show a faster decline than emissions in the Eurelectric Power Choices scenario, which seems to allow a higher degree of flexibility to reach the targets set for 2050. Furthermore, the sharp increase of CO2-certificate prices in the Eurelectric Power Choices scenario from 2030 onwards partly results from the assumed removal of mandatory RES-targets after 2020. Therefore, carbon prices gain high importance to deliver required emission reductions by 2050.

Figure 2: Development of CO2-certificate prices, in EUR_{2008}/t CO2



On the other hand, assumed geographical extension of emission trading systems (e.g. in the ECF Pathways, WEO 450 ppm and the Power Choices scenario international carbon markets are assumed not later than 2020) can be interpreted to prevent carbon prices from rising unlimited. This effect is due to more abundant and cheap opportunities for emission reduction outside the EU/OECD.

Relatively low prices for emission certificates in the Greenpeace/EREC study may be partly determined by the idea that the process of emission trading remains unclear and is not able to help RES energy expansion (and is thus not considered adequate to become an important parameter for Greenpeace/EREC in their model).

In summary, the pre-defined importance of carbon prices as an instrument in different scenario studies may also explain their different resulting price levels (e.g. in the Power Choices scenario, carbon prices are assumed to be important to reach emission targets).

Regarding investment costs,

- All scenarios confronted with high emission reduction requirements estimate a considerable increase in capital expenditure. Even baseline scenarios suggest an increase in capital expenditure in the coming years. The somewhat higher estimation in the emissions reduction scenarios is generally based on several effects: higher capital intensity of RES technologies in terms of costs per power produced and the need for higher power transmission capacity due to intermittency of most of the expected new RES (investment in power transmission capacity is roughly estimated to be 20-50 % higher in most of the alternative scenarios, compared to Baseline or Reference scenarios); higher capital intensity of new NUC and CCS investments. The scenarios also agree in the estimation of lower expenses for FOS fuels in due course due to large substitutions of RES for FOS fuels and energy efficiency improvements.

- Overall, these effects lead to somewhat different total cost results across scenarios with large methodological uncertainties, strongly influenced by different modelling mechanisms (e.g. cost-optimization vs. accounting frameworks), framework parameters (e.g. price developments; see above) and conventions for cost-estimations. Furthermore, results are often not available for the same timeframes and geographical boundaries.

- Results on future investment costs are also strongly influenced by the chosen assumptions on technological developments in energy transformation and end-user applications. A lot depends on learning rates For example, in ECF, learning rates are 5% for wind offshore/onshore, 15% for solar PV and 12% for CCS and yearly reductions in investments costs per capacity are estimated at 1% for biomass and geothermal plants, compared to 0,5% for FOS-fired plants.

- Table 4 shows compliance costs available in alternative scenarios, differentiated into total costs and grid costs or investment:

Table 4: Comparison of Compliance and Grid Costs/Investment in Alternative Scenarios

Scenario	Estimated compliance costs/investment	Estimated grid costs/investment	Comments
IEA – WEO 450 ppm	▪ EU-27: +1600 bn USD (vs. Ref.) cumulative investment in the energy sector (incl. grid costs) till 2035	▪ Global: 5100 bn USD (20% lower vs. Ref.) cumulative investment till 2035	▪ External costs not included (except GHG) ▪ Grid investment (Ref.): 25% transmission, 75% distribution
IEA – ETP Blue Map	▪ EU-27: additional cumulative investment (energy sector) compensated by cumulative fuel savings: 7100 bn USD vs. 13100 bn USD till 2050 (vs. Bas.)	▪ Global: 12300 bn USD (incl. smart grids) cumulative grid-investment till 2050 (+50% vs. Bas.)	▪ Grid investment (Ref.): 30% transmission, 70% distribution ▪ Back-up costs may be considered implicitly
EU DG ENER Ref.	▪ ~175 bn € p.a. (2030) capital and O&M costs in power generation (i.e. 51,0 €/MWh)	▪ EU-27: grid costs of 10,8 €/MWh (2030) vs. 7,4 (2010), i.e. ~165 bn € cumulative grid costs	▪ Distribution grid not included ▪ Back-up costs

			considered implicitly
▪ ECF Roadmap 80% RES	▪ Lower fuel costs dominate capital cost expenses: overall -80 bn € in 2020 (-205 bn € in 2030) vs. Ref.	▪ Cumulative additional transmission capex: 95-129 bn €, additional back-up capex: 63-99 bn € (vs. Ref.) ▪ Cumulative additional distribution capex: 200-300 bn €	▪ Amount by which distribution costs are incremental to the Ref. is unclear
Energy [R]evolution Advanced	▪ Global: 292 bn USD add. investment p.a. 2007-2030 (vs. Ref.) ▪ 42 bn € additional investment p.a., fuel savings of 62 bn € p.a. (2007-2050, vs. Ref.)	▪ Costs of 209 bn € p.a. for the assumed new European "Supergrid"	▪ Grid costs estimated externally, cost structure of grid costs not further specified
Eurelectric Power Choices	▪ Capital and O&M costs of 53,3 €/MWh in 2030	▪ Grid-costs rise from 7,3 to 12,6 €/MWh (2050) ▪ Cumulative grid investment: 1.500 bn € (+35% vs. Baseline)	▪ No external costs besides CO2-costs ▪ Not clear if back-up costs are considered implicitly
FEEM et al. - Planets	▪ Global: ~800 (2030) and 2500 (2050) bn € yearly costs (i.e. 1-2,5 % of GDP)	▪ n/a	▪ Costs are measured as consumption losses vs. the Reference scenario

- Table 4 shows that:
    - A comparison of total cost results from the different scenario studies is hardly possible as the underlying assumptions on methods and data used are in most cases not presented sufficiently transparently to give a clear picture on the dependability of figures presented (see also above discussion about grid costs).
    - Macroeconomic costs or benefits are not provided, so the net economic cost or benefit (e.g. including the gains or losses from competitiveness factors) are not available.
    - Distribution costs are hardly ever estimated although they seem to represent the majority of necessary grid investments. This makes it doubtful that costs for infrastructure changes are realistically included in most scenarios.

Regarding electricity prices,

- Electricity prices increase in most of the studies at least in the medium term (up to 2030). Some studies with high emission reduction targets expect a decrease of electricity prices in the long term (up to 2050), mainly driven by lower consumption of FOS fuels in the power sector in combination with assumed technological improvements for RES power plants. Not all studies actually calculate electricity prices for a market environment with supply of and demand for electricity. Therefore Table 5, providing an overview on electricity prices and their main drivers, displays electricity generation costs as a proxy for electricity prices in these cases.

Table 5: Comparison of Properties of Electricity Prices in the Different Scenarios

Study and scenario	Electricity price/cost developments	Main drivers
IEA – WEO Ref and 450 ppm	▪ No data for Europe	▪ No data for Europe
IEA – ETP Ref and Blue Map	▪ No data for Europe	▪ No data for Europe
EU DG ENER Reference	▪ 1.4% average annual rise 2000-2030, declining after 2025	▪ Increasing fuel prices, higher capital costs of RES, NUC and CCS, auctioning of CO2-allowances
EU DG ENER Baseline	▪ 1.5% average annual rise 2000-2030, declining after 2025	▪ Increasing fuel prices, higher capital costs of RES, NUC and CCS, auctioning of CO2-allowances
ECF Roadmap Reference	▪ n/a	▪ Carbon prices, fossil-fuel prices, technology learning rates
ECF Roadmap Pathways	▪ Higher levelised costs of electricity (LCOE) than in the Ref. (short term), slightly higher LCOE by 2050	▪ Carbon prices, fossil-fuel prices, technology learning rates
Energy [R]evolution	▪ Generation costs increase up to 2020, upward tendency until 2050	▪ Fossil fuel prices, technology improvements of RES-technologies, costs for CO2-allowances
Energy [R]evolution Advanced	▪ Generation costs increase up to 2030 and decrease afterwards (-34-43 % 2050 compared to the Baseline)	▪ Fossil fuel prices, technology improvements of RES-technologies, costs for CO2-allowances
Eurelectric Baseline	▪ Strong increase up to 2025, stabilization afterwards	▪ Fossil fuel prices, restructuring of the power plant fleet
Eurelectric Power Choices	▪ Strong increase up to 2025, slight decrease afterwards	▪ Fossil fuel prices, restructuring of the power plant fleet, lower fossil fuel consumption and lower demand for CO2-allowances)
FEEM et al. – Planets	▪ Electricity prices stay almost constant	▪ Restructuring of power generation
FEEM et al. – Planets Fb 3.2	▪ Increase until 2015, stagnation 2015 to 2035, sharp increase after 2035	▪ Restructuring of power generation, increasing electricity demand

Key points:

- The economic performances of all energy technologies – FOS, NUC and RES – are reflected by their specific generation costs which are heavily influenced by assumed future fuel and carbon prices, and assumed technology learning rates.
- Technology-neutral studies, such as from IEA, DG ENER or Eurelectric, give high importance to the carbon price as a key driver to deploy the most competitive low-carbon technologies and leave it then to the market to develop the future energy mix.
- Comparison of total costs for developing a more sustainable EU energy system by 2050 is hardly possible due to lack of transparency in most scenarios on methodological and data assumptions.
- Most scenarios seem to lack a realistic consideration of the costs for necessary infrastructure changes. For example, although investments in the distribution grid represents the majority of necessary grid investments, in almost all scenarios only transmission costs (if at all) are considered.
- Electricity prices increase in most of the studies at least in the medium term (2030).

3.3 Assumptions on Social Issues

The most important effect in the EU social structure considered in the scenarios is change in size of population. Throughout the studies, a slight increase of the EU population is expected in the medium term (immigration), with the tendency to a stabilised population in the long term. Some studies also assume a significant decrease in the size of households.

However, in none of the scenarios analyzed evidence on fundamental changes in the behavioural patterns of the economic agents was found.

Some studies (e.g. PRIMES-based Eurelectric, DG TREN, FEEM) apply fixed microeconomic decisions of economic agents concerning demand for energy related products and investment in energy supply equipment. These scenarios partly take into account different levels of risk-awareness of agents (higher levels for individuals than for enterprises, reflected by high discount rates for individuals), lack of information, market barriers for new technologies and rebound-effects in energy-efficiency investments. Investment decisions are modelled under full information and perfect foresight assumptions.

Only very little information concerning trends and effects on the labour market was found in the studies. However, in some scenarios (ECF pathways, Energy [R]evolution) sectorial shifts on the labour market from traditional energy sectors (e.g. FOS fuels) to sectors linked to RES installations are expected. Magnitudes of these effects are very differently estimated, usually ignoring the related loss of employment and market leadership in more traditional sectors.

The risk of loss of global competitiveness of energy intensive industries and related deindustrialisation in Europe is usually not considered explicitly.

Issues of public acceptance regarding deployment of new power plants (large-scale RES, new NUC, low-carbon FOS), new RES-support infrastructure (pan-European grid, large storage) or new enforced consumer behaviour (smart metering) are nowhere explicitly modelled (implicitly only for NUC by assuming e.g. growth rates being much more limited than economic optimisation would suggest).

Key points:

- Only few studies explicitly model changes in the behaviour of economic agents with regard to changes in consumer behaviour or public acceptance of deployment of new power generation plants and RES-support infrastructures,
- Effects on the EU labour market and the economy as a whole (e.g. risk of deindustrialisation) as a consequence of visions of a future EU energy mix are not consistently modelled in any scenario study and are usually limited to presenting short-term positive effects of preferred technological solutions.

3.4 Further Technology Assumptions

The following conclusions on technology assumptions in the different scenarios are in addition to the technology-related assumptions already evaluated and compared under *Sections 3.1 (Policy Assumptions and Targets)* and *3.2 (Economic Assumptions)*:

- In all of the studies, a Baseline or Reference scenario is compared with scenarios which are more ambitious in reducing GHG-emissions. These "GHG-ambitious scenarios" mostly assume significant growth rates in RES energy sources for power generation (up to shares of e.g. 50% in the ETP Blueline and 97% in the Energy [R]evolution scenario by 2050) and agree on the main RES electricity generation technologies: onshore/offshore wind, biomass and solar-PV.

- The studies are more diverse regarding the estimations for the shares of thermal and hydro-RES: Of course, higher shares of FOS fuels are estimated in the absence of additional policies promoting RES-deployment. In the scenarios with more ambitious emission-reduction policies, gas-fired power plants often have a high relevance in serving peak-loads and load-following, due to the high shares of variable RES sources. Nuclear power plants, without t restrictions on development, are often considered as a vital option to help significantly reducing GHG-emissions from power generation in a cost-effective way (e.g. ETP Blueline).

- Innovative solutions for road transport (electric vehicles, biofuels) and other new power and energy technologies are identified as crucial for future energy systems throughout the studies. Most of the studies focus on electric vehicles and biofuels besides power sector restructuring.

- The scope for biomass technology improvements to 2050 is not explored in most cases, nor is the prospect of productivity increases driven by rising demand for biomass.

- Most of the studies emphasize the importance of policies concerning end-user efficiency (residential and industrial energy demand) and some studies describe measures in this field as crucial factors in the short run (2010 to 2030) to reach the emission targets set for the long run (e.g. ETP Blueline). The proposed measures comprise the thermal integrity of buildings, heat pumps, technological development in the processes of energy-intensive industries and more energy-efficient vehicles.

- Efficiency considerations on the one hand affect end-user efficiency and on the other hand the energy transformation sector (mainly power generation). There is little information on the latter and if, the studies estimate improvements in the efficiency of traditional power generation technologies, but only small ones compared to current state of the art (e.g. in the ECF Reference efficiencies of 60 % are assumed for CCGT-plants and 50 % for coal-fired plants in 2050).

- In most scenarios except those of ECF, grid development is not modelled or optimised for the given energy mix; it is pre-determined. Given the expected burst in electrification, the role of "smart grid" technology developments, increased balancing needs and distributed generation, the assumptions about grid development equate to assumptions regarding costs and energy mixes.

Key points:

In addition to the technology-related "Key points" already presented at the end of Sections 3.1 (Policy Assumptions and Targets) and 3.2 (Economic Assumptions), the following key conclusions on technology assumptions in the different scenarios can be made:

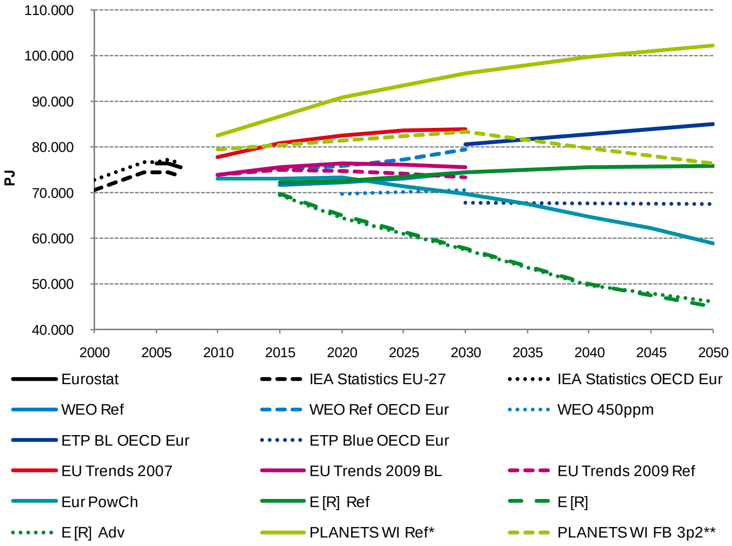
- Most scenarios assume significant growth rates in the use of RES energy sources for power generation.
- NUC, without restrictions on development, is often considered as a vital option to help significantly reducing GHG-emissions from power generation in a cost-effective way.
- Competitiveness of CCS depends strongly on the carbon price.
- Problems in extended use of biomass needed to counter-balance future shares of intermittent wind and solar are nowhere analysed in detail.
- Estimated future investment costs are strongly influenced by chosen assumptions on technological developments in energy technologies..
- Innovative solutions for road transport (electric vehicles, biofuels) are identified as crucial for future energy systems throughout the studies.
- Most studies emphasize the importance of policies concerning end-user efficiency (residential and industrial energy demand) and some studies describe measures in this field as crucial factors in the short run to reach emission targets set for the long run.

3.5 Key Results of Scenarios

From the above modelling assumptions taken by different stakeholders, scenario models result in often different, sometimes similar projections regarding specific future trends:

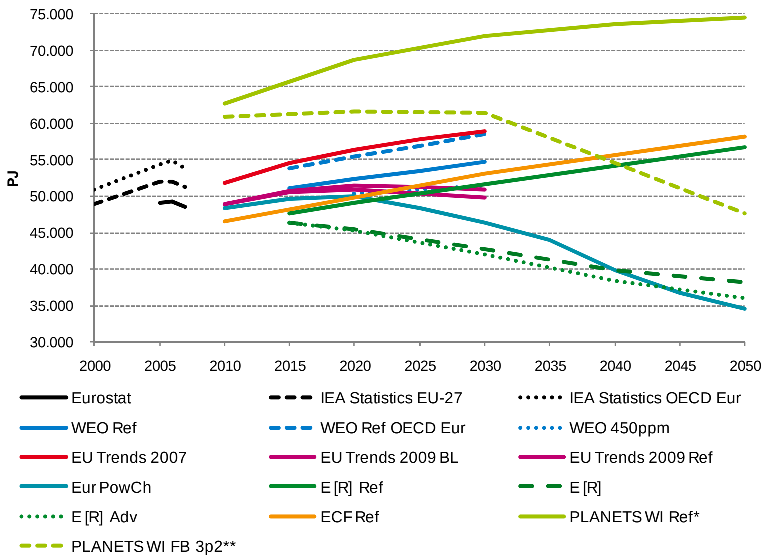
- **Future primary energy demand** has to be seen in relation with the final energy demand and the technologies used. As shown in Figure 3, whereas the baseline scenarios show generally slightly increasing primary energy demands, the alternative scenarios aiming at reducing GHG-emissions show generally declining demands:

Figure 3: Development of Economy-Wide Primary Energy Demand, in PJ



- As can be seen from Figure 4, without new energy policies to reduce energy demand or GHG-emissions, **final energy demand** will increase, similar to GDP-development. With new stringent policy measures, final energy demand can be reduced by 20-25% until 2050.

Figure 4: Development of Economy-Wide Final Energy Demand, in PJ

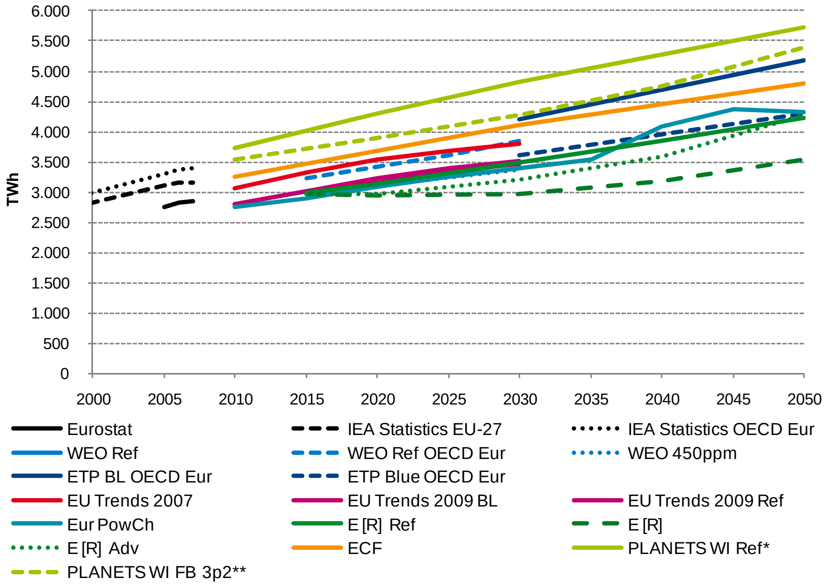


- Compared to primary energy demand, long term developments in final energy demand are also influenced by the structure of the power generation sector (see Figure 4).

- It has to be noted, that in some cases, differences in **efficiency targets** may lead to major differences in projected energy demand. For example, ambitious energy efficiency measures are implemented in the Greenpeace/EREC Energy [R]evolution scenarios and in the Eurelectric Power Choices scenario, even in the medium term up to 2020. This results in significant declines of final energy demand and also primary energy demand, if measures aim at reducing energy demand of end-consumers.

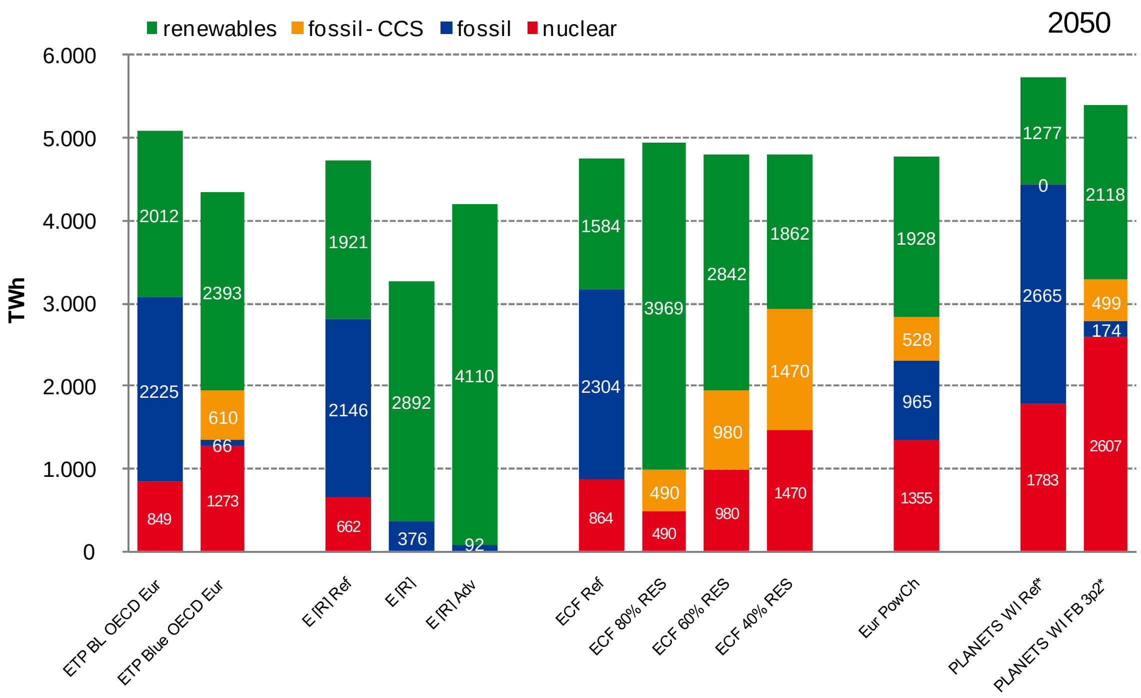
- Looking at **future electricity demand**, a steady increase can be seen in all scenarios. Compared to the picture of the final energy demand, in general a substitution towards electricity can be observed. This tendency is especially relevant for scenarios with high GHG-reduction targets as these scenarios focus on decarbonisation of power generation and substitution for FOS fuels in transportation (e.g. electric vehicles) and buildings (e.g. heat pumps). Generally, this substitution process is induced through cost-optimization, either for individuals (DG ENER, Eurelectric), or for the whole region (e.g. ECF, FEEM), with the exception of the Greenpeace/EREC Energy [R]evolution scenarios. Beneath this substitution effect, electricity demand also increases due to higher income and economic activity. Figure 5 clearly shows that reductions in electricity demand due to energy-efficiency policies are outweighed by additional demand caused by the mentioned factors.

Figure 5: Development of Economy-Wide Electricity Demand, in TWh



- The **changes in electricity generation** (development as well as structure), which are shown in Figure 6 for 2050 depend on:
  - GHG and RES targets set in the scenarios,
  - competitiveness of power plants assumed differently in different scenarios (capital costs, fixed and variable O&M costs, fuel and CO2-prices),
  - pre-defined RES-targets set in "back-casting" scenarios (Greenpeace/EREC, ECF),
  - bounds set for deployment of NUC/CCS in some scenarios (Greenpeace/EREC, ECF).

Figure 6: Electricity Generation in 2050, in TWh



In the medium term, up to 2030 and especially up to 2020, differences between the alternative scenarios are relatively small. Of course, even in the medium term, differences between scenarios with emission reduction targets and reference scenarios are considerable: Ambitious scenarios generally show higher shares for RES and NUC, with diverse views on CCS, except when NUC and CCS are excluded from the beginning.

In the long term, even differences between alternative scenarios are considerable. In the Eurelectric Power Choices and the ETP Blueline scenarios, nuclear power plants are estimated to obtain a high relevance in reaching the emission reduction targets. Nuclear power plants are assumed to be the most economic option to serve baseload in these scenarios, whereas FOS-fuelled plants are mainly used for load following (gas-fired plants), with the exemption of coal-fired plants with CCS. Differences between the two scenarios could be due to slightly different geographical coverage (ETP focusing on OECD-Europe, including Norway and Switzerland, both with high RES-shares) and differences in the estimated competitiveness of CCS / FOS fuels vis-à-vis NUC and RES power generation.

Deployment of CCS is of importance for all alternative scenarios (except Energy [R]evolution where it is excluded), but significantly higher in the Power Choices scenario and the ECF-pathways. Deployment for this form of emission abatement starts typically in the period from 2020 to 2030, but is assumed to gain importance only after 2030 (ETP, ECF, Eurelectric, PLANETS). The outcomes in the basic and advanced Greenpeace/EREC Energy [R]evolution scenarios are significantly different, due to exclusion of NUC and CCS in these scenarios.

In the low carbon scenarios examined, the quantity of electricity from RES produced by 2050 ranges from 1862 TWh to 4110 TWh. Fossil fuel generated electricity deploying CCS ranges from 490 TWh to 1470. Nuclear powered electricity production ranges from 490 TWh to 2607 TWh.

Key points:

- Without new energy policies to reduce energy demand or GHG-emissions, final energy demand will increase, similar to GDP-development.
- The significant differences across scenarios on assumptions on feasibility of efficiency improvements lead to major differences in projected energy demand.
- Compared to primary energy demand, long term developments in final energy demand are also influenced by the structure of the power generation sector. Higher decreases of final energy demand in relation to primary energy demand can be achieved by a technology-neutral approach in developing future power generation mixes (i.e. resulting in higher shares for CCS and NUC).
- Electricity demand increases across all scenarios due to higher income and economic activity. Reductions due to energy-efficiency policies are outweighed by additional demand.
- If a technology-neutral approach is chosen, high prices of CO2-certificates are the main driver for deployment of both RES and NUC, but also for development of CCS. Therefore, GHG-ambitious technology-neutral scenarios generally show higher shares for RES and NUC, except when NUC and CCS are excluded from the beginning.

3.6 Models Used and Interdependencies Between Studies

In all scenario studies analysed bottom-up models are used, some of them in combination with top-down models, as summarised (for the main models) in Table 6:

Table 6: Characteristics of Models Used

Study	Models used	Type of model	Characteristic
IEA - WEO	▪ World Energy Model	▪ Bottom-up-model (with additive top-down model)	▪ Simulation
IEA - ETP	▪ ETP MARKAL/TIMES	▪ Bottom-up-model	▪ Optimization (lead costs)
EU DG TREN	▪ PRIMES	▪ Mixed representation: Bottom-up and top-down model	▪ Partial market equilibrium
ECF Roadmap	▪ a.o. McKinsey Power Generation Model	▪ Bottom-Up-Model (with additive top-down model)	▪ Simulation
Greenpeace/EREC Energy [R]evolution	▪ MESAP/PlaNet	▪ Bottom-up model	▪ Simulation
Eurelectric Power Choices	▪ PRIMES	▪ Mixed representation: Bottom-up and top-down model	▪ Partial market equilibrium

Not least because of the use of the same models by different scenario studies, a variety of studies uses the input and output of other studies.

Two main studies can be indentified: IEA World Energy Outlook and DG ENER / PRIMES.

- The IEA Energy Technology Perspectives, the ECF Roadmap 2050, Eurelectric's Power Choices and Greenpeace/EREC's Energy [R]evolution use the WEO baseline.
- Input and output of the DG ENER PRIMES study are used for the Eurelectric study.

4. SUMMARY OF COMPARISON

From the comparison of stakeholder scenarios presented in this report, the following conclusions can be drawn:

- **Overall Goal:**
  - Scenarios are marked by GHG and/or RES targets and development of future energy mixes is primarily based on optimising this parameter.
  - Security of supply indicators are not created (or optimised), except for the grid-oriented modelling of ECF.
  - Competitiveness indicators are limited, partial and not optimised.
- **Basic Modelling Approaches used by Stakeholders:**
  - Models used for scenario studies can broadly be grouped into market-based optimisation models ("fore-casts") and models which use exogenously defined market shares ("back-casts").
  - If market-based optimisation is applied (i.e. a technology-neutral approach chosen), deployment of the different energy technologies (FOS, NUC, RES) mainly depends on their relative total costs.
  - Grid modelling (and its major implications) are modelled by ECF; in most other scenario analyses, they are pre-determined.
- **Energy/Electricity Demand:**
  - Without new policy measures demand will increase due to GDP growth. Final energy consumption in 2030 in low carbon scenarios range from 41000 PJ to 61000 PJ; in 2050 from 34000 PJ to 49000 PJ.
  - Electrification is assumed in (almost) all scenarios. Electricity is estimated to gain higher shares in final energy demand, especially in scenarios confronted with ambitious GHG-targets (mainly as a substitute for fossil fuels).
- **Development of More Sustainable Future Energy Systems:**
  - Most scenarios, such as those generated by the PRIMES model, optimise to determine the final energy mix ("technology neutrality"), based on cost input and technology learning assumptions. Greenpeace/EREC and the ECF scenarios backcast from several targeted generation shares, the former excluding NUC and CCS...
  - Estimated future investment costs are also strongly influenced by chosen assumptions on technological developments in energy technologies whose dependability is often difficult or impossible to verify.
  - Most scenarios seem to lack a clear consideration of the costs for necessary infrastructure changes to enable further deployment of variable RES. For example, although investments in the distribution grid seem to represent the majority of necessary grid investments and although all studies stress the

importance of smart grids, in almost all scenarios merely transmission (if at all) is considered.

  - Few studies explicitly model changes in the behaviour of economic agents with regard to changes in consumer behaviour.
  - Effects on the EU labour market and the economy as a whole (e.g. risk of deindustrialisation) are not consistently modelled in any scenario study.
  - Electricity prices increase in most studies at least in the medium term (2030). Some studies with high emission reduction targets expect a decrease of electricity prices in the long term (up to 2050), due to lower fossil-fuel consumption.

- **Renewables:**
  - Absolute and relative increases of RES in the power sector across all scenarios.
  - Investment costs for RES decrease across all scenarios, especially in a long term perspective.

- **Nuclear Power:**
  - When optimised purely on costs, nuclear power tends to expand and gain increasing shares.

- **Fossil fuel plants:**
  - CCS plays an increasing role in scenarios with a focus on a strong future role of the carbon price.

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