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Energy Baseline Scenarios for the Clean Air for Europe (CAFE) programme

PRIMES model v.2

Final Report to DG Environment

SERVICE CONTRACT TO VERIFY CONSISTENCY BETWEEN AIR QUALITY AND CLIMATE CHANGE POLICIES IN THE CAFE BASELINE SCENARIOS
Contract No 070501/2004/377552/MAR/C1

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Energy Baseline Scenarios for the Clean Air for Europe (CAFE) programme

Use of the model PRIMES

1. Introduction

The Clean Air For Europe (CAFE) programme of the European Commission aims at a comprehensive assessment of current and expected air quality and of the relevant measures for further improving European air quality beyond the achievements expected from the full implementation of all present air quality legislation. For this purpose, CAFE has compiled a set of baseline projections outlining the consequences of present legislation on the future development of emissions, of air quality and of health and environmental impacts up to the year 2020.

For this purpose the PRIMES model has been used for all EU-25 Member States, building upon the energy baseline scenario constructed in the context of the "Long Range Energy Modelling" (LREM) framework contract[1,2] financed by the Directorate-General for Energy and Transport. This report illustrates the future evolution of the EU-25 energy system in the horizon to 2020 for:

- a "climate policy" scenario, which assumes for the year 2020 a carbon price of 20 € per t CO_2 , achieving a 3.6 percent reduction of the EU-25 CO_2 emissions in 2020 compared to 1990 (the "climate policy" CAFE baseline scenario), and
- an "illustrative climate" scenario, assuming a carbon price of 90 € per t CO_2 in 2020. This scenario results in a reduction of the EU-25 CO_2 emissions by close to 20 percent compared to the year 1990.

The "climate policy" CAFE baseline scenario uses as a starting point the LREM baseline scenario but also incorporates:

- Climate policy measures (which are not explicitly included in the LREM Baseline)
- Comments and projections provided by EU-25 Member States, maintaining however a Europe-wide consistency in assumptions about energy prices, imports and exports of electricity etc.
- Revised macroeconomic assumptions reflecting latest trends

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[1] Mantzos, L., Capros, P., Kouvaritakis, N., Zeka-Paschou M. (2003): European Energy and Transport: Trends to 2030. European Commission – Directorate General for Energy and Transport, ISBN 92-894-4444-4, Office for Official Publications of the European Communities, Luxembourg, 2003.

[2] Mantzos, L., Capros, P., Zeka-Paschou M. (2004): European Energy and Transport: Scenarios on key drivers. European Commission – Directorate General for Energy and Transport, ISBN 92-894-6684-7, Office for Official Publications of the European Communities, Luxembourg, 2004.

- Latest data as regards the evolution of the EU-25 power generation sector

The “illustrative climate” scenario is identical to the “climate policy” CAFE baseline scenario, assuming however higher carbon prices that lead to larger reductions of CO_2 emissions in the EU-25 energy system in the horizon to 2020.

In the following a detailed description of the assumptions and results of the CAFE baseline scenarios, as well as a comparison to those of the LREM Baseline scenario, are provided.

2. Main assumptions of the “Climate Policy” Scenario

The key assumptions used for the “Climate Policy” CAFE Baseline Scenario as well as the changes made in comparison to the LREM Baseline scenario are presented in the following.

2.1. Demographic and weather assumptions

Population plays an important role in both the overall economic performance and energy trends, especially in the transportation, household and services sectors. In the “Climate Policy” Baseline scenario, population figures were, for consistency purposes, unchanged from the LREM baseline, though a number of Member States provided their own projections. Thus, for the EU-15 Member States EUROSTAT figures have been used both as regards historical data and projections for the evolution of population in the EU-15 Member States. As regards new Member States (NMS) population data and short-term projections were taken from the EUROSTAT database, whereas population growth rates beyond 2003 and over the horizon to 2020 were derived from the UN Centre for Human Settlements.

On the basis of these assumptions the EU-25 population is projected to remain rather stable, peaking in 2020 at some 462 million (see Table 2-1).

Table 2-1: Population trends in the EU-25, 1990 to 2020

	Million inhabitants			
	1990	**2000**	**2010**	**2020**
EU15	366.01	378.69	387.83	390.45
NMS	75.12	74.73	73.40	71.67
EU-25	441.13	453.41	461.23	462.11
	annual growth rate			
	90/00	**00/10**	**10/20**	**00/20**
EU15	0.34	0.24	0.07	0.15
NMS	-0.05	-0.18	-0.24	-0.21
EU-25	0.28	0.17	0.02	0.10

Source: EUROSTAT, Global Urban Observatory and Statistics Unit of UN-HABITAT, PRIMES.

Household size (i.e. number of persons per household) is another key demographic factor playing a significant role in the growth of energy demand in households. Following UN projections that are used in the CAFE baseline scenario (unchanged from the LREM ones), household size in the EU-25 will experience a significant decline from 2.4 persons in 2000 to 2.1 persons in 2020 reflecting rising life expectancy, combined with declining birth rates and changes in societal and economic conditions. This trend gives rise to significant growth in the number of households, which increase by 32 million between 2000 and 2020 (+17.3% in 2000-2020) despite the rather stable evolution of population (see Table 2-2).

Table 2-2: Number of households in EU-25, 1990 to 2020

	Million households			
	1990	2000	2010	2020
EU15	141.25	157.67	174.21	187.33
NMS	25.72	28.11	30.03	30.53
EU-25	166.97	185.78	204.24	217.86
	annual growth rate			
	90/00	00/10	10/20	00/20
EU15	1.11	1.00	0.73	0.87
NMS	0.89	0.66	0.17	0.41
EU-25	1.07	0.95	0.65	0.80

Source: Global Urban Observatory and Statistics Unit of UN-HABITAT, PRIMES.

Weather conditions, which are important in determining both the intensity and the overall pattern of energy use (mainly as regards heating requirements), are assumed to remain unchanged over the projection period, i.e. the degree-days parameter is taken as constant at 2000 levels.

2.2. Macroeconomic assumptions

The economic growth assumptions are based on those used in the LREM Baseline scenario but have been updated so as to reflect recent trends, incorporating Economic and Financial Affairs DG forecasts of April 2004 for the short term, as well as Member States views as regards their future economic growth to the extent that they do not generate inconsistencies as regards the overall EU-25 economic outlook. Overall economic growth in the EU-25 is projected to reach 2.3% pa in 2000-2020.

In 2000-2020 GDP growth is projected to reach at 2.3% pa (see Table 2-3). Economic growth is limited to just 2.0% pa in 2000-2010 but increases significantly thereafter to reach 2.6% pa in 2010-2020. The convergence of Member States' economies (including NMS) is assumed to continue over the projection period. Furthermore, the integration of new Member States into the European Union is assumed to generate accelerated growth for their economies especially beyond 2010.

Table 2-3: Evolution of gross domestic product in EU-25, 1990 to 2020

	000 MEuro'00			
	1990	2000	2010	2020
EU15	6982	8545	10365	13346
NMS	333	394	562	831
EU-25	7315	8939	10927	14177
	annual growth rate			
	90/00	00/10	10/20	00/20
EU15	2.04	1.95	2.56	2.25
NMS	1.70	3.60	3.99	3.80
EU-25	2.03	2.03	2.64	2.33

Source: EUROSTAT, Economic and Financial Affairs DG, PRIMES.[3]

[3] Incorporating results obtained from the WEFA study and GEM-E3 model runs (this applies to all the macroeconomic assumptions). WEFA (now integrated into DRI-WEFA) is an economic consultancy company which, in the context of the Long Run Energy Modelling framework contract, was subcontracted by NTUA to deliver a consistent macro-economic and sectoral forecast over the horizon to 2020 for the EU Member States and, at a more aggregate level, for candidate countries and EU neighbouring countries (Norway and Switzerland). This projection was delivered in March 2001.

The Baseline assumptions reflect also the long established trend of structural changes in developed economies, away from the primary and secondary sectors and towards services and high value-added products (less material and energy-intensive products), however with a pace that decelerates in the long run. Table 2-4 illustrates the projected evolution of value added in the EU-25 in the Baseline scenario.

Table 2-4: Evolution of sectoral value added in EU-25

	000 MEuro'00			
	1990	**2000**	**2010**	**2020**
Gross Value added	**6833**	**8351**	**10356**	**13442**
Industry	1486	1698	2076	2645
Energy intensive	430	495	604	767
Non Energy intensive	1055	1203	1472	1878
Construction	431	439	503	621
Services	4482	5709	7258	9608
Agriculture	198	222	238	270
Energy branch	236	283	282	297
	annual growth rate			
	90/00	**00/10**	**10/20**	**00/20**
Gross Value added	**2.03**	**2.18**	**2.64**	**2.41**
Industry	1.34	2.03	2.45	2.24
Energy intensive	1.40	2.01	2.43	2.22
Non Energy intensive	1.32	2.04	2.46	2.25
Construction	0.18	1.36	2.14	1.75
Services	2.45	2.43	2.84	2.64
Agriculture	1.12	0.69	1.29	0.99
Energy branch	1.84	-0.04	0.53	0.24

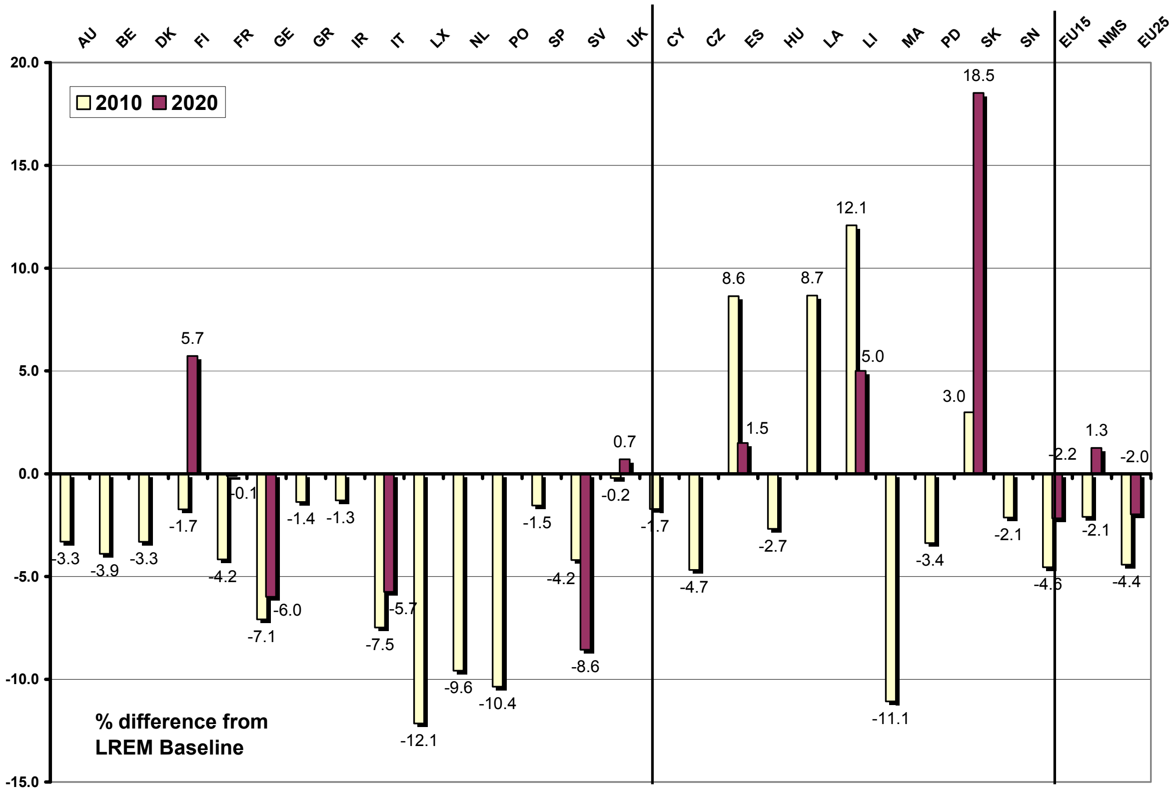
Source: EUROSTAT, Economic and Financial Affairs DG, PRIMES.

The sector that grows above average over the projection period is that of services with its market share reaching 71.5% in 2020 from 68.4% in 2000. This increase occurs to the detriment of all other sectors of the economy. The market share of industrial activity, which grows at rates slightly below average, declines by 0.6 percentage points over the projection period (from 20.3% in 2000 to 19.7% in 2020).

2.2.1. Comparison to the LREM Baseline scenario

The introduction of the latest forecasts of Economic and Financial Affairs DG forecasts (April 2004) for the short term in the “Climate Policy” CAFE Baseline Scenario leads to significant changes as regards the evolution of the EU economy in the horizon to 2010. Thus, at the EU-25 level, GDP is projected to be some 4.4% less than in the LREM Baseline (see Figure 2-1) with the impact of the revision of assumptions being more pronounced in the EU-15 (-4.6% from LREM Baseline levels in 2010). In 2020, the change from the LREM Baseline levels becomes less pronounced (-2.0% at the EU-25 level). This decline in the difference of economic growth in the “Climate Policy” CAFE Baseline Scenario from the LREM Baseline is largely due to the assumption made in the context of the study that for the Member States that did not provide their own projection on economic development, the slowdown of economic growth by 2010 will be followed by accelerated growth thereafter. Thus, in 2020 the GDP for those Member States reaches at the same levels to those projected in the LREM Baseline.

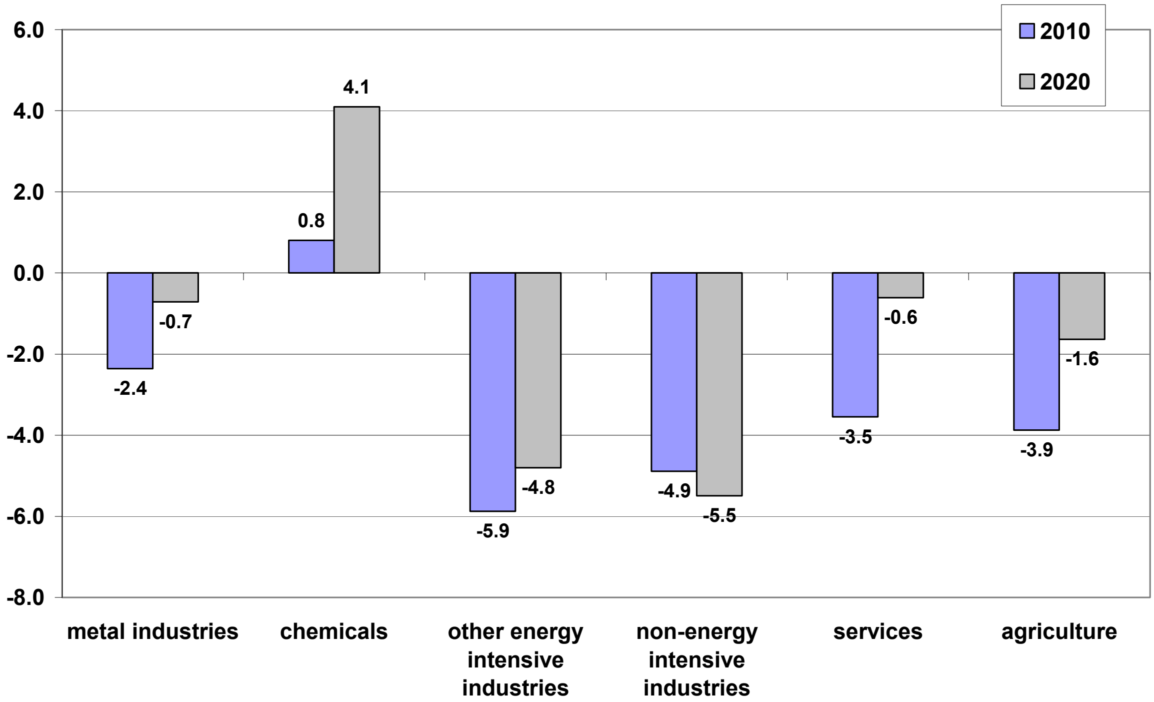
Figure 2-1: Change in GDP by Member State (% difference from LREM Baseline levels)



Source: PRIMES

The slowdown of economic activity in the short term and the introduction of country specific assumption for the long run lead also to changes as regards the structure of the EU economy, as the different sectors are not affected in a uniform manner (see Figure 2-2). Economic activity in the chemical sector is projected to grow at rates above those in the LREM Baseline scenario, mainly as a result of a much higher growth in the pharmaceuticals and cosmetics industries, whereas all other sectors grow at rates below the LREM Baseline. Services and metal industries increase their market share in the EU economy (as the decline from LREM Baseline levels remains below the corresponding decline of GDP over the projection period. The same is the case for the agricultural sector. On the contrary, the market share of other industrial sectors declines compared to the LREM Baseline levels.

Figure 2-2: Change in value added by sector in EU-25 (% difference from LREM Baseline levels)



Source: PRIMES

It should be noted that the above changes are largely driven by the country specific assumptions introduced in the analysis as one would expect that a slowdown in economic growth would lead to a delay in the dematerialisation of the EU economy.

2.3. International fuel prices

The evolution of primary fuel prices is illustrated in Table 2-5. The assumptions in the "Climate Policy" CAFE Baseline scenario remain unchanged to those of the LREM Baseline. The projections for international fuel prices derive from the output of the POLES model[4] and are based on the important assumption that global energy markets will remain well supplied at a relative modest cost throughout the projection period.

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[4] The POLES model is a global sectoral model of the world energy system. The development of the POLES model has been partially funded under the JOULE II and JOULE III programmes of Research DG (DG-XII) of the European Commission. Since 1997 the model has been fully operational and can produce detailed long term (2030) world energy and CO_2 emission outlooks with demand, supply and price projections by main region. The model splits the world in 26 regions. For the model design see the model reference manual: *"POLES 2.2. European Commission, DG XII, December 1996"*.

Table 2-5: International price assumptions

	Average border prices in the EU-25 ($00/boe)			
	1990	**2000**	**2010**	**2020**
Crude oil	27.9	28.0	20.1	23.8
Natural gas	15.6	15.5	16.8	20.6
Hard coal	13.1	7.4	7.2	7.0
		annual growth rate		
		1990-2000	**2000-2010**	**2010-2020**
Crude oil		0.03	-3.27	1.74
Natural gas		-0.06	0.80	2.06
Hard coal		-5.60	-0.25	-0.22

Source: POLES

2.4. Policy assumptions

The policy assumptions used in the "Climate Policy" CAFE Baseline scenario draw on the corresponding assumptions of the LREM Baseline scenario. Thus, the "Climate Policy" CAFE Baseline scenario takes into account existing policies and those in the process of being implemented at the end of 2001 (for tax rates in mid 2002). Assumptions include, for example, the modernisation of the EU economy and the completion of the internal electricity and gas markets, certain policies to support renewables and energy efficiency (e.g. the fuel efficiency agreement with the car industry) as well as the nuclear phase-out decisions in certain Member States. Energy policies that aim to promote renewable energy (wind, small hydro, solar energy, biomass and waste) are assumed to continue, involving subsidies on capital costs and preferential electricity selling prices. However, rather than imposing the indicative targets of the EC renewables electricity Directive[5] for each Member State, the Baseline includes the policy measures in place for such targets in the Member States. The same approach was retained as regards the implementation of the Directive 2003/30 on renewable energy in transport.[6]

However, the implementation of the renewables electricity Directive 2001/77 of September 2001 is not included. This applies also to Directive 2003/30 on renewable energy in transport and any additional follow-up Directives.

One of the key differences between the "Climate Policy" CAFE Baseline scenario and the LREM Baseline relates to the treatment of policy initiatives related to climate change. In the LREM Baseline scenario no specific new policies and measures aiming at meeting Kyoto targets in 2008-2012, and possible more severe ones in the future are assumed to be implemented over the next 25 years. On the contrary, in the "Climate Policy" CAFE Baseline scenario the existence of an EU-wide trading regime is assumed from 2010 onwards. The permit price ranges from 12 € per t of CO_2 in 2010 to 16 € in 2015 and 20 € in 2020 leading to adjustment of the behaviour of economic agents through changes in relative fuel prices.

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[5] European Commission Directive 2001/77/EC of the European Parliament and of the Council on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market. Brussels, 27 September 2001. Also at:

http://europa.eu.int/eur-lex/pri/en/oj/dat/2001/l_283/l_28320011027en00330040.pdf

[6] European Commission Directive 2003/30/EC of the European Parliament and of the Council on the promotion of the use of biofuels or other renewable fuels for transport. Brussels, 8 May 2003. Also at:

http://europa.eu.int/comm/energy/res/legislation/doc/biofuels/en_final.pdf

In addition country specific comments on the implementation of policy measures and the future evolution of the energy system have been taken into account and introduced in the "Climate Policy" CAFE Baseline scenario to the extent possible.

2.5. Assumptions for the power generation sector

The Baseline scenario assumes that all capacity expansion and decommissioning plans in power generation, already decided, would take place as indicated in the EURPROG report of EURELECTRIC and other statistical sources (e.g. EPIC)[7]. Beyond 2010 plant decommissioning occurs on the basis of technical lifetimes and agreed policies on nuclear phase-out.

In the "Climate Policy" CAFE Baseline scenario capacity expansion and decommissioning schedules have also been revised so as to take into account the latest developments in the power sector. Furthermore, it has been assumed that no new power generation units except those that are already in the process of being constructed, with the exemption of small units with short construction time (mainly wind turbines), can enter the power system in 2005.

Finally, country specific projections as regards the future evolution of import and exports of electricity across EU Member States have been incorporated in the scenario assumptions after performing the appropriate adjustments so as to maintain a consistent outlook for imports and exports of electricity at the EU-25 level. This was necessary as keeping the country specific projections would mean that the EU-25 would import some 61 TWh of electricity from other countries (equivalent to approximately 6 new nuclear power stations with a nominal capacity of 1300 MW each). The approach retained was to respect the country specific projections for the Member States that are net exporters of electricity and appropriately adjust the projections for the Member States that are importers of electricity so as to limit overall imports for the EU in 2020 at 22 TWh (compared to 24 TWh in the LREM Baseline).

3. "Climate Policy" CAFE Baseline Scenario results

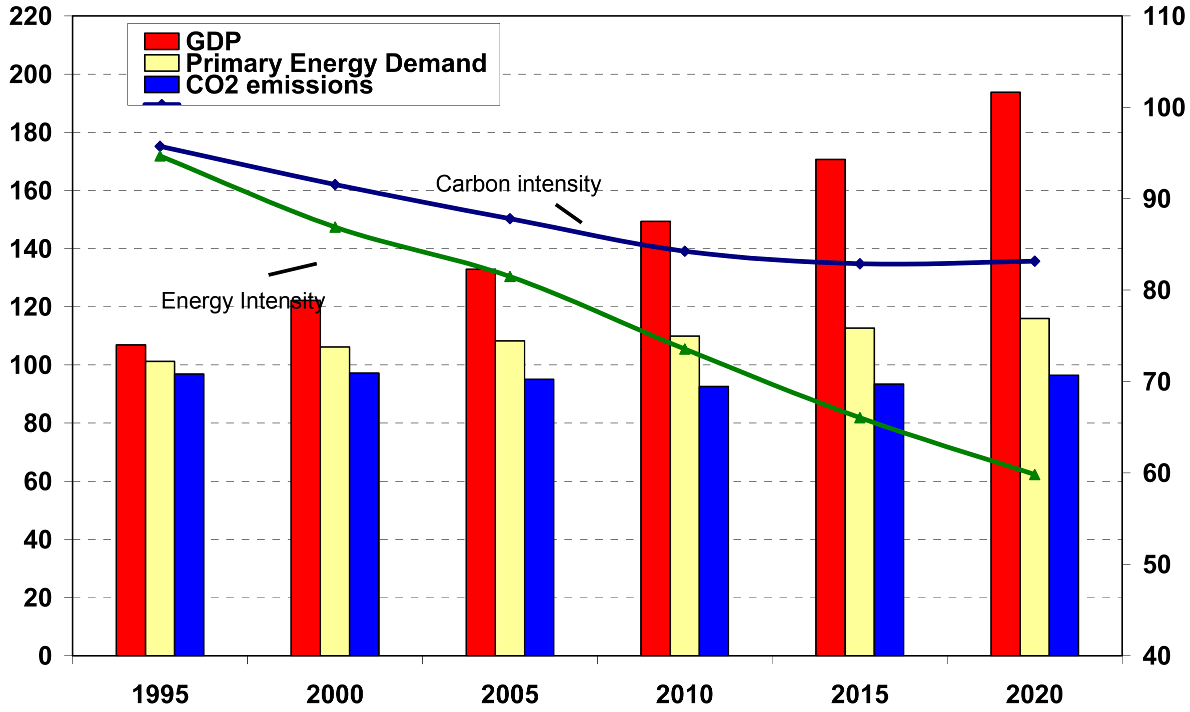
3.1. Main Findings

The projected evolution of the EU-25 energy system in the "Climate Policy" CAFE Baseline scenario shows that despite the evidence of a further de-linking of economic growth from energy demand in the EU-25, energy demand is expected to continue to grow. Primary energy demand in the EU-25 increases during the period 2000 to 2020 by 9.2% compared to a growth in GDP of 58.6%, implying that the energy intensity of the EU-25 energy system (expressed as primary energy demand per unit of GDP) will improve at a rate of 1.85% pa. Improvements in energy efficiency (both on the demand and the supply sides), changes in the structure of EU industry, saturation in demand for some important energy needs, and the policies already in place are some of the key drivers for the projected intensity gains. In the presence of an EU-wide CO_2 emissions trading regime, CO_2 emissions are projected to exhibit a further decline to that observed in the near past (in 1990 to 2000 CO_2 emissions changed by -2.8% whereas the corresponding primary energy needs grew by 6.2%) being limited in 2010 to -7.4% from 1990 levels. However, beyond 2010 and as available options for changes in the fuel mix

[7] EURPROG report of 2002. The Epic database, developed by ESAP SA, gives a technical description, unit by unit, of power generation capacity. For EU-25 it contains more than 26,500 units above 100 kW. More information is available at www.esap.be.

towards the use of less carbon intensive energy forms become increasingly exploited, a worsening of carbon intensity is projected to occur with CO_2 emissions in 2020 changing by -3.6% from 1990 levels. The links between GDP, energy use and CO_2 emissions growth from 1990 to 2020 (with energy and carbon intensity plotted against the secondary axis) are illustrated in Figure 3-1.

Figure 3-1: EU-25 primary energy indicators (index 1990=100), 1995-2020



Source: PRIMES.

3.2. Primary Energy Needs

Indigenous production of primary energy in the EU-25 declines continuously over the projection period (see Table 3-1). The most pronounced decline is projected for solid fuels, primary production of which is limited in 2020 to 42% of that observed in 2000 as a result of the increasing competitiveness of imported coal and natural gas but also the adoption of climate policy measures. The exhaustion of currently exploited reserves and the limited scope for the exploitation of new, more costly ones in a world of relatively modest energy prices is the key driver for the decline in the production of crude oil and natural gas (-38% and -25% respectively from 2000 levels by 2020) in EU25. In the same period production of crude oil in Norway is also projected to exhibit a decline, being limited by 2020 to about 75% of the levels observed in 2000, whereas that of natural gas exhibits a strong increase above present levels (more than doubling in 2020 from 2000 levels).

Table 3-1: Primary production of fuels in EU-25

	Mtoe			
	1990	**2000**	**2010**	**2020**
Solid Fuels	350.8	203.4	126.3	84.8
Hard coal	236.2	135.7	82.9	60.0
Lignite	114.5	67.6	43.3	24.8
Liquid Fuels	120.3	163.5	130.9	101.9
Natural Gas	139.6	196.6	193.2	147.6
Nuclear	196.9	237.7	242.1	198.8
Renewable En. Sources	69.2	96.1	142.4	179.6
Total	**877**	**897**	**835**	**713**
EU-15	708	761	723	616
NMS	169	136	112	96
	Annual Growth Rate (%)			
	90/00	**00/10**	**10/20**	**00/20**
Solid Fuels	-5.3	-4.7	-3.9	-4.3
Hard coal	-5.4	-4.8	-3.2	-4.0
Lignite	-5.1	-4.4	-5.4	-4.9
Liquid Fuels	3.1	-2.2	-2.5	-2.3
Natural Gas	3.5	-0.2	-2.7	-1.4
Nuclear	1.9	0.2	-2.0	-0.9
Renewable En. Sources	3.3	4.0	2.3	3.2
Total	**0.2**	**-0.7**	**-1.6**	**-1.1**
EU-15	0.7	-0.5	-1.6	-1.1
NMS	-2.1	-1.9	-1.5	-1.7

Source: PRIMES.

Nuclear production remains rather stable at 2000 levels until 2010 but exhibits a strong decline thereafter (-16.5% in 2020 from 2000 levels) as a result of the closure of nuclear plants with safety concerns in some new Member States (namely Lithuania and Slovakia) and the nuclear phase-out policies decided in certain EU-15 Member States (namely Belgium, Germany and Sweden).

Policy measures and technological progress, combined to the existence of a CO_2 emissions trading regime, are the key drivers for the significant boost in the production of renewable energy forms (+87% in 2000-2020) that by 2020 become the second most important indigenous energy (after nuclear) in the EU-25 energy system.

Contrary to the decline in indigenous energy production, primary energy needs are projected to grow from 2000 to 2020 by 14.4% (see Table 3-2). Solid fuels (-3.1% pa in 2000-2020) and nuclear energy (-0.9% pa) are the energy forms that are projected to exhibit a decline from 2000 levels. Natural gas (+2.5% pa) and renewable energy forms (+3.2% pa) are projected to remain the fastest growing fuels in the EU-25 energy system (as was the case during the last decade). Primary energy demand for liquid fuels exhibits moderate growth over the projection period (+0.1% pa) though at a rate well below average. Novel energy forms, such as hydrogen and methanol, are not projected to make significant inroads in the EU-25 energy system in the period to 2020 under Baseline conditions.

Table 3-2: Primary energy demand in EU-25

	Mtoe			
	1990	**2000**	**2010**	**2020**
Solid Fuels	431	303	209	160
Liquid Fuels	596	636	622	647
Natural Gas	259	376	490	615
Nuclear	197	238	242	199
Renewable En. Sources	69	96	142	180
Total	**1554**	**1651**	**1708**	**1802**
EU-15	1321	1453	1505	1582
NMS	234	198	203	221
	Annual Growth Rate (%)			
	90/00	**00/10**	**10/20**	**00/20**
Solid Fuels	-3.4	-3.7	-2.6	-3.1
Liquid Fuels	0.6	-0.2	0.4	0.1
Natural Gas	3.8	2.7	2.3	2.5
Nuclear	1.9	0.2	-2.0	-0.9
Renewable En. Sources	3.3	4.0	2.3	3.2
Total	**0.6**	**0.3**	**0.5**	**0.4**
EU-15	1.0	0.4	0.5	0.4
NMS	-1.6	0.2	0.9	0.5

Source: PRIMES.

The strong shift towards the use of renewable energy more than counterbalances the projected decline of nuclear energy leading to a declining dependency on fossil fuels, the share of which is limited to 78.9% in 2020 from 79.6% in 2000. However, the impact of the closure of nuclear installations is evident as in 2010 the share of fossil fuels in the EU-25 energy system is limited to 77.4%. The market share of renewable energy forms is projected to reach 10% of primary energy needs in 2020 (8.3% in 2010) from 5.8% in 2000. Significant changes also occur in the fossil fuel mix. Thus, following a substantial decline during the last decade (from 27.7% of primary energy needs in 1990, down to 18.4% in 2000), the share of solid fuels is projected to decline further, accounting for 8.9% of primary energy needs in 2020. Liquid fuels are also projected to exhibit a modest decline, with their market share reaching 35.9% in 2020 compared to 38.5% in 2000. In contrast natural gas, spurred by its rapid penetration both on the demand and the supply sides, accounts by 2020 for 34.1% of primary energy needs (+11.3 percentage points compared to 2000 levels).

The significant growth in the use of natural gas combined to the declining primary production results in an increase of import dependency for the EU-25 energy system from 47.2% in 2000 up to 61.6% in 2020 (see Table 3-3).

Table 3-3: Import dependency in EU-25

	%			
	1990	**2000**	**2010**	**2020**
Solid fuels	17.5	30.1	39.5	47.1
Liquid fuels	80.9	76.6	80.5	85.5
Natural gas	47.6	49.5	60.6	76.0
Total	**44.8**	**47.2**	**52.5**	**61.6**
EU-15	47.6	49.4	53.4	62.3
NMS	28.3	30.8	45.1	56.6

Source: PRIMES.

By 2020 some 85.5% of EU-25 oil demand will be satisfied by imports compared to 76.6% in 2000, whereas the import dependency for natural gas is projected to reach 76% in 2020, an increase of 26.5 percentage points from 2000 levels. As regards the import dependency of solid fuels it is also projected to grow, reaching 47.1% in 2020 from 30.1% in 2000, despite the projected decline in primary energy needs, reflecting the increasing competitiveness of imported coal against indigenous production.

3.3. Final Energy Demand projections

Final energy demand in the EU-25 is projected to increase at rates well above those of primary energy needs and in 2020 will be 18.4% higher than in 2000 (compared to a +14.4% increase for primary energy needs). This difference reflects the significant changes that are projected to occur in the power generation sector leading to considerable improvements in energy efficiency.

The evolution of energy demand by sector for the EU-25 energy system is illustrated in Table 3-4. Energy demand in industry is projected to grow at rates slightly below average (+16.6% in 2000 to 2020). Industrial value added in the same period increases by 55.8%. Structural changes towards less energy-intensive manufacturing processes and the exploitation of energy saving options and changes in the fuel mix towards fuels permitting higher in use efficiency are the key drivers for this de-linking of industrial activity from energy demand leading to energy intensity gains of 1.4% pa.

Table 3-4: Final energy demand in EU-25 by sector

	Mtoe			
	1990	**2000**	**2010**	**2020**
Industry	327.2	309.1	329.9	360.4
Domestic	408.8	433.3	460.1	501.9
Tertiary	140.7	154.2	161.8	184.0
Households	268.1	279.1	298.2	317.9
Transport	273.7	332.0	372.5	410.3
Total	**1010**	**1074**	**1162**	**1273**
EU-15	859	955	1033	1123
NMS	150	119	129	150
	Annual Growth Rate (%)			
	90/00	**00/10**	**10/20**	**00/20**
Industry	-0.6	0.7	0.9	0.8
Domestic	0.6	0.6	0.9	0.7
Tertiary	0.9	0.5	1.3	0.9
Households	0.4	0.7	0.6	0.7
Transport	1.9	1.2	1.0	1.1
Total	**0.6**	**0.8**	**0.9**	**0.9**
EU-15	1.1	0.8	0.8	0.8
NMS	-2.3	0.8	1.5	1.2

Source: PRIMES.

Even more pronounced energy intensity gains are projected for the tertiary sector with energy needs growing at a rate of 0.9% pa while economic activity increases by 2.6% pa. The restructuring of the new Member States' economies (involving a more rational use of energy in the context of increasing energy prices), technological improvements (both in buildings and equipment), changes in the fuel mix, and saturation effects in many end uses are some of the reasons for the limited growth of household energy needs (+0.7% pa in 2000 to 2020).

As was the case in 1990 to 2000, the transport sector remains the fastest growing segment in the EU-25 demand side. Increasing transport requirements and shifts towards the use of more energy intensive transport means (passenger cars and aviation in passenger transport, road freight in freight transport) more than counterbalance the significant improvement of vehicles efficiency leading to an increase of energy needs in the sector in 2020 by 23.6% from 2000 levels. By 2020 the transport sector accounts for 32.2% of energy needs in the demand side (from 30.9% in 2000), industry for 39.4% (from 40.3%), households for 25.0% (from 26%) and the tertiary sector for 14.5% (14.4% in 2000).

Significant changes also occur in the demand side fuel mix (see Table 3-5) as a result of the projected shifts towards the use of more efficient and less carbon intensive energy forms. Solid fuels exhibit a continuous decline over the projection period accounting by 2020 for just 2.5% of energy needs in the EU-25 demand side (from 5.3% in 2000 and 11.7% in 1990). Liquid fuels remain the main energy carrier in the EU-25 energy demand sectors over the projection period, but grow at rates well below average, constantly losing market share. By 2020 some 76% of liquid fuels demand is projected to arise from the transport sector, compared to 67% in 2000.

Table 3-5: Final energy demand in EU-25 by fuel

	Mtoe			
	1990	2000	2010	2020
Solid Fuels	117.7	57.4	38.0	31.7
Liquid Fuels	424.2	464.2	483.7	516.1
Gas fuels	196.2	245.7	286.7	311.6
Steam	62.9	55.6	63.1	75.4
Electricity	176.5	211.3	245.7	291.0
New fuels (hydrogen etc.)	0.0	0.0	0.3	1.0
Biomass	25.9	32.1	34.3	33.0
Waste	5.8	7.5	8.7	9.5
Other renewables	0.5	0.8	1.9	3.2
Total	**1010**	**1074**	**1162**	**1273**
	Annual Growth Rate (%)			
	90/00	**00/10**	**10/20**	**00/20**
Solid Fuels	-6.9	-4.0	-1.8	-2.9
Liquid Fuels	0.9	0.4	0.7	0.5
Gas fuels	2.3	1.6	0.8	1.2
Steam	-1.2	1.3	1.8	1.5
Electricity	1.8	1.5	1.7	1.6
New fuels (hydrogen etc.)	-	-	12.9	-
Biomass	2.2	0.7	-0.4	0.1
Waste	2.6	1.6	0.9	1.2
Other renewables	4.6	10.0	5.2	7.5
Total	**0.6**	**0.8**	**0.9**	**0.9**

Source: PRIMES.

Natural gas demand is projected to grow at rates above average (+1.2% pa in 2000 to 2020) but decelerates beyond 2010 due to limitations in infrastructure but also technological factors. Electricity demand is projected to exhibit the highest growth over the period (+1.6% pa in 2000-2020) as a result of the increasing number of processes, appliances and applications that can use energy only in the form of electricity, but also issues related to the favourable characteristics of electricity (easy controllability, cleanliness at the point of use, etc.). Similar growth rates are projected for distributed steam (+1.5% pa). The exploitation of cogeneration opportunities is partly responsible for the limited increase in the use of biomass while the fall in the number of rural households also contributes in this direction. In contrast, demand for waste grows over the projection period through its increasing use in industry. Novel final energy forms, such as hydrogen and ethanol, do not progress significantly primarily because of cost considerations. Finally, other renewable energy forms, such as solar energy used in water heaters, grow quite rapidly (+7.5% pa in 2000-2020) but they remain insignificant as a proportion of overall final consumption.

3.4. Electricity and steam generation

As discussed in the preceding section, electricity and co-generated steam are the fastest growing energy carriers in the demand side. Electricity production is projected to grow by 1.4% pa in 2000 to 2020 (compared to a growth of +1.6% pa in the demand side) as a result of improvements in the energy sector and in the distribution and transmission network (see Table 3-6).

Table 3-6: Electricity requirements by sector in EU-25[8]

	TWh			
	1990	**2000**	**2010**	**2020**
Industry	922	1042	1189	1358
Tertiary	504	651	777	980
Households	568	695	819	975
Transports	58	69	73	71
Energy sector	268	266	274	294
Trans. and distr. Losses	160	201	206	200
(Net imports)	25	25	21	22
Electricity generation	**2456**	**2898**	**3316**	**3856**
EU-15	2139	2574	2926	3366
NMS	317	324	390	490
	Annual Growth Rate (%)			
	90/00	**00/10**	**10/20**	**00/20**
Industry	1.2	1.3	1.3	1.3
Tertiary	2.6	1.8	2.4	2.1
Households	2.0	1.7	1.8	1.7
Transports	1.7	0.6	-0.2	0.2
Energy sector	-0.1	0.3	0.7	0.5
Trans. and distr. Losses	2.3	0.2	-0.3	0.0
(Net imports)	-0.1	-1.6	0.3	-0.6
Electricity generation	**1.7**	**1.4**	**1.5**	**1.4**
EU-15	1.9	1.3	1.4	1.4
NMS	0.2	1.9	2.3	2.1

Source: PRIMES.

Similar trends prevail and as regards co-generated steam production, which is projected to grow by 1.4% pa (compared to +1.5% pa in the demand side).

Table 3-7: Distributed steam requirements by sector in EU-25[9]

	TWh			
	1990	**2000**	**2010**	**2020**
Industry	423	344	413	516
Tertiary	111	101	106	128
Households	197	202	215	233
Energy sector	42	26	25	20
Trans. and distr. Losses	32	34	30	30
Total	**805**	**708**	**789**	**928**
EU-15	438	516	609	727
NMS	367	192	180	201
	Annual Growth Rate (%)			
	90/00	**00/10**	**10/20**	**00/20**
Industry	-2.0	1.9	2.2	2.0
Tertiary	-0.9	0.4	1.9	1.2
Households	0.2	0.6	0.8	0.7
Energy sector	-4.7	-0.6	-1.8	-1.2
Trans. and distr. Losses	0.7	-1.1	0.0	-0.6
Total	**-1.3**	**1.1**	**1.6**	**1.4**
EU-15	1.7	1.7	1.8	1.7
NMS	-6.3	-0.7	1.1	0.2

Source: PRIMES.

The shift towards the decentralisation of electricity and steam production, projected to occur over the outlook period, as well as technological progress allowing for smaller-

[8] Electricity consumption in refineries as well as on-site auto-consumption of electricity in the power generation sector are included in the energy sector.

[9] Including on-site consumption of non-marketed steam from industrial co-generation units.

scale distribution networks, are the key drivers for the further growth of distributed steam demand in the EU-25 and the reversal of past trends. Industry is projected to remain the dominant user of steam over the outlook period (see Table 3-7), with the tertiary and households sectors exhibiting growth at rates below average.

Increasing energy requirements for electricity and steam lead to a large expansion of installed capacity in the EU-25 energy system, which is projected to increase by 290 GW between 2000 and 2020 (close to 50% of installed capacity in 2000; see Table 3-8). Installed capacity of natural gas combined cycle units, boosted by both technological advances and the progressive deregulation of electricity markets, exhibits a significant growth over the projection period accounting by 2020 for 36% of total installed capacity compared to just 7% in 2000. Installed capacity of small gas turbines is also projected to grow by a factor of 3 over the outlook period. As a result, gas fuelled power plants account for more than 40% of total EU-25 generating capacity in 2020 compared to 10.7% in 2000.

Table 3-8: Power generation capacity by type of plant in EU-25, 1995-2020.

	GW_e			
	1995	**2000**	**2010**	**2020**
Nuclear	134.7	140.3	131.6	105.2
Large Hydro (pumping excl.)	91.2	94.1	97.9	98.2
Small hydro	2.0	2.1	8.2	14.2
Wind	2.5	12.8	92.1	143.9
Other renewables	0.0	0.2	0.5	1.0
Thermal plants	386.9	406.7	467.6	597.7
of which cogeneration plants	87.3	103.4	132.6	169.0
Open cycle - Fossil fuel	343.8	335.6	258.7	154.2
Clean Coal and Lignite	0.0	0.0	0.5	1.1
Supercritical Polyvalent	0.0	0.0	0.6	35.1
Gas Turbines Combined Cycle	20.4	47.4	171.4	346.2
Small Gas Turbines	22.0	22.8	35.3	59.8
Fuel Cells	0.0	0.0	0.0	0.0
Geothermal	0.7	1.0	1.2	1.3
Total	**617**	**656**	**798**	**960**
EU-15	539	579	703	824
NMS	79	78	95	136
	% share			
	1995	**2000**	**2010**	**2020**
Nuclear	21.8	21.4	16.5	11.0
Large Hydro (pumping excl.)	14.8	14.3	12.3	10.2
Small hydro	0.3	0.3	1.0	1.5
Wind	0.4	1.9	11.5	15.0
Other renewables	0.0	0.0	0.1	0.1
Thermal plants	62.7	62.0	58.6	62.2
of which cogeneration plants	14.1	15.8	16.6	17.6
Open cycle - Fossil fuel	55.7	51.1	32.4	16.1
Clean Coal and Lignite	0.0	0.0	0.1	0.1
Supercritical Coal	0.0	0.0	0.1	3.7
Gas Turbines Combined Cycle	3.3	7.2	21.5	36.1
Small Gas Turbines	3.6	3.5	4.4	6.2
Fuel Cells	0.0	0.0	0.0	0.0
Geothermal	0.1	0.2	0.2	0.1
Total	**100**	**100**	**100**	**100**
EU-15	87.3	88.2	88.1	85.8
NMS	12.7	11.8	11.9	14.2

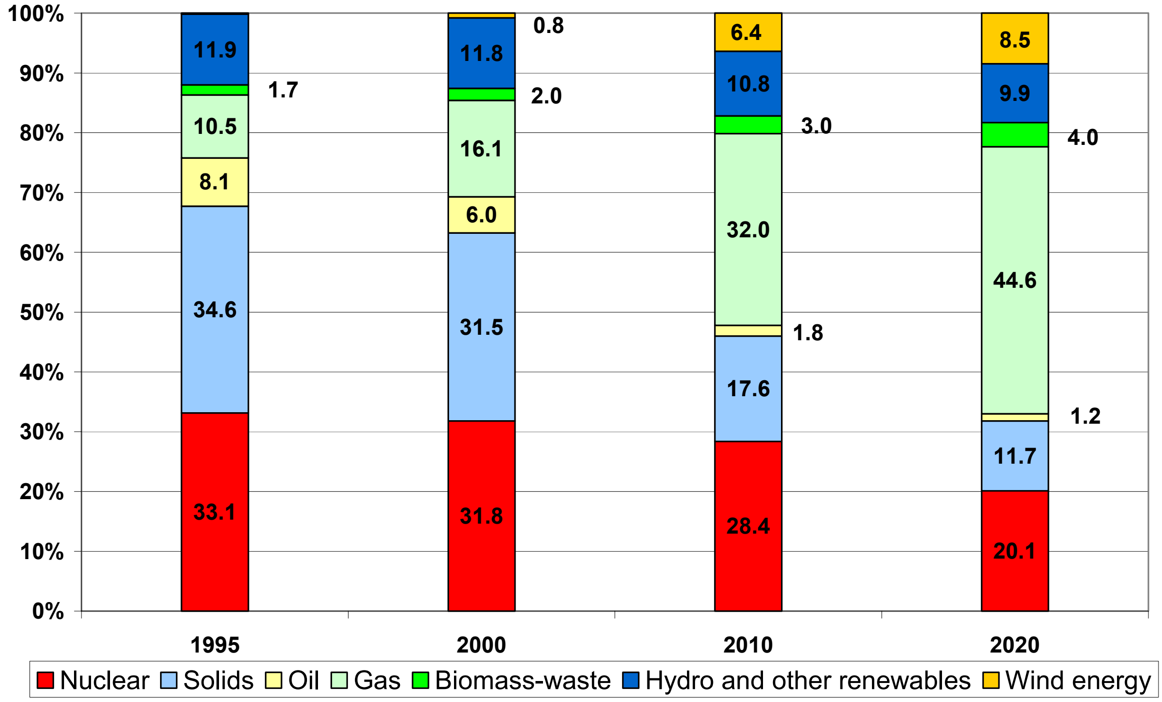
Source: PRIMES.

This growth of gas-fired power plants occurs mainly to the detriment of conventional fossil fuel and nuclear power plants. Installed capacity of conventional thermal power plants (open cycle monovalent and polyvalent units) is projected to decline very rapidly both in absolute terms and as a share of total installed capacity. By 2020, they are projected to represent approximately 16% of total installed capacity compared to more than 51% in 2000. Nuclear capacity also declines as a result of the closure of unsafe nuclear plants in NMS, the nuclear phase-out policies in certain EU-15 Member States, and the decommissioning of existing nuclear plants beyond 2015 (with economic actors not replacing all of them with new nuclear plants on economic grounds). Thus, by 2020 nuclear capacity accounts for 11% of total installed capacity in the EU-25 (from 21.4% in 2000).

Supercritical polyvalent units (with scope for burning coal, lignite, biomass and waste) make some inroads by 2020 as they constitute a cost effective option in replacing retired nuclear power plants while other clean coal technologies (e.g. IGCC and PFBC) are not projected to become a cost-effective option, on the basis of the currently prevailing technology forecasts for power generation. By 2020 installed capacity of supercritical polyvalent plants is projected to reach 35 GW (or 12.8% of total installed capacity).

Renewable energy forms play an important role in the evolution of the power generation sector, despite the rather limited capacity expansion in hydropower plants over the outlook period; a result of the already high exploitation of suitable sites in the EU-25 energy system. In the presence of climate policy incentives and supportive policies for renewable energy forms, wind turbine capacity is projected to reach 144 GW (15% of total installed capacity) in 2020 compared to less than 13 GW in 2000.

Figure 3-2: Electricity generation by fuel in EU-25



Source: PRIMES.

Changes in power generation capacities are also reflected in the structure of electricity generation by energy form (see Figure 3-2). Nuclear energy and solid fuels are projected to lose market share continuously such that in 2020 they account for 20.1% and 11.7% respectively compared to 31.8% and 31.5% in 2000. The emerging gap is largely covered by greater use of natural gas, which beyond 2010 is projected to become the main energy input for electricity generation. In 2020 close to 45% of total electricity produced is projected to come from natural gas compared to 16.1% in 2000.

The contribution of renewable energy in power generation is also projected to grow over time, reaching some 22.2% of total electricity production in 2020 from 14.6% in 2000, despite the fact that the limited potential for further exploitation and, consequently, the declining share of electricity generation from hydropower partly offsets the increasing contribution of wind energy in electricity generation, taking into account the rapidly growing electricity demand.

As a result of the increasing contribution of renewable energy forms, the decline in the use of nuclear energy (with efficiency typically between 33-35%) and the investment choices of electricity generators towards technologies with high conversion efficiencies, such as gas turbine combined cycle plants, fuel input in power generation is projected to remain stable over the projection period (+0.1% pa in 2000 to 2020) despite the significant growth in both electricity and steam generation. As illustrated in Table 3-9, natural gas grows at rate of 4.6% pa accounting for 43% of fuel consumption by 2020 compared to 18% in 2000. A marked growth is also projected for biomass (+6.6% pa) and, to a less extent waste (+3.4% pa) but even in 2020 their aggregate market share is not projected to exceed 7.5% (from 2.8% in 2000).

Table 3-9: Fuel use for electricity generation in EU-25

	Mtoe			
	1995	**2000**	**2010**	**2020**
Hard coal	153.6	144.5	102.2	79.0
Lignite	67.5	65.6	42.3	24.4
Oil products	53.9	41.5	16.3	11.9
Gas	70.0	112.6	182.4	275.5
Biomass	6.2	8.0	14.4	29.0
Waste	7.4	9.5	16.7	18.6
Nuclear energy	215.3	237.7	242.1	198.8
Geothermal Heat	2.1	3.0	3.4	3.6
Total	**576**	**622**	**620**	**641**
EU-15	496	541	532	549
NMS	80	81	88	92
	Annual Growth Rate (%)			
	95/00	**00/10**	**10/20**	**00/20**
Hard coal	-1.2	-3.4	-2.5	-3.0
Lignite	-0.6	-4.3	-5.3	-4.8
Oil products	-5.1	-8.9	-3.1	-6.1
Gas	10.0	4.9	4.2	4.6
Biomass	5.4	6.0	7.3	6.6
Waste	5.0	5.8	1.1	3.4
Nuclear energy	2.0	0.2	-2.0	-0.9
Geothermal Heat	6.6	1.4	0.6	1.0
Total	**1.6**	**0.0**	**0.3**	**0.1**
EU-15	1.7	-0.2	0.3	0.1
NMS	0.3	0.8	0.5	0.6

Source: PRIMES.

The rapid growth in the use of natural gas and biomass/waste occurs to the detriment of nuclear energy (-0.9% pa in 2000 to 2020) and solid fuels (-3.0 pa for hard coal and -4.8% pa for lignite). By 2020 solid fuels account for just 16% of total fuel input in the power generation sector compared to 34% in 2000. The share of nuclear energy also declines to reach 31% in 2020 (7 percentage point less than in 2000). The significant improvement that is projected to occur in the power generation sector through the above mentioned changes is clearly reflected on the thermal electricity production efficiency, which increases by 11 percentage points between 2000 and 2020 to reach 48%.

3.5. The outlook for energy-related CO_2 emissions

CO_2 emissions in the EU-25 energy system are projected to continue to decline in the horizon to 2010 (-0.5% pa in 2000 to 2010) as was the case in the last decade (-0.3% pa in 1990-2000) despite the projected growth of primary energy needs. The continuation of the restructuring of new Member States' economies, the structural shifts towards less energy intensive uses, technological progress and changes in the fuel mix all contribute to the projected further decoupling between energy demand and CO_2 emissions growth in the EU-25 energy system. However, beyond 2010 as structural shifts become less pronounced and potential changes in the fuel mix are increasingly exploited, a reversion of trends occurs with CO_2 emissions growing at rates slightly lower to those of primary energy needs (+0.4% versus +0.5% pa in 2010-2020). As a result by 2020 CO_2 emissions are projected to reach levels similar to those observed in 2000 (see Table 3-10).

Table 3-10: CO_2 emissions by sector in EU-25

	Mt CO_2			
	1990	**2000**	**2010**	**2020**
Industry	713.2	605.7	521.5	524.8
Tertiary	256.8	236.7	220.1	224.9
Households	519.7	462.6	459.9	468.0
Transports	794.6	967.5	1067.2	1164.6
Electricity-steam production	1240.0	1193.3	1063.3	1101.2
District heating	101.0	35.1	16.9	10.9
New fuels (hydrogen etc.) prod.	0.0	0.0	0.2	1.2
Energy branch	144.2	164.0	140.4	139.2
Total	**3769**	**3665**	**3489**	**3635**
EU-15	3082	3118	2973	3102
NMS	687	547	517	533
	Annual Growth Rate (%)			
	90/00	**00/10**	**10/20**	**00/20**
Industry	-1.6	-1.5	0.1	-0.7
Tertiary	-0.8	-0.7	0.2	-0.3
Households	-1.2	-0.1	0.2	0.1
Transports	2.0	1.0	0.9	0.9
Electricity-steam production	-0.4	-1.1	0.4	-0.4
District heating	-10.0	-7.0	-4.3	-5.7
New fuels (hydrogen etc.) prod.	-	-	19.9	-
Energy branch	1.3	-1.5	-0.1	-0.8
Total	**-0.3**	**-0.5**	**0.4**	**0.0**
EU-15	0.2	-0.5	0.4	0.0
NMS	-4.5	-0.6	0.3	-0.1

Source: PRIMES.

The only sectors in which CO_2 emissions in 2020 are projected to reach levels above those observed in 2000 are the transport (+20.4% in 2020) and households (+1.2%) sectors. In all other sectors CO_2 emissions in 2020 remain below 2000 levels despite the fact that they are projected to grow from 2010 to 2020. From 2010 onwards the transport sector becomes the sector with the highest share of total CO_2 emissions emitted by the EU-25 energy system (30.6% in 2010 rising to 32.0% in 2020, whereas the corresponding share in 2000 was no more than 26.4%) followed by the electricity and steam generation sector that accounts for 30.5% of CO_2 emissions in 2010 and 30.3% in 2020 compared to 32.6% in 2000.

In the "Climate Policy" CAFE Baseline Scenario the carbon intensity (CO_2 emissions per unit of primary energy needs) of the EU-25 energy system improves by 9% between 2000 and 2020 (see Table 3-11). The bulk of this improvement occurs between 2000 and 2010 while after 2015 carbon intensity worsens and CO_2 emissions rise accordingly but remain below 1990 levels (-4% in 2020).

Table 3-11: Key indicators for the EU-25 energy system

	Index (1990 = 100)			
	1990	**2000**	**2010**	**2020**
Gross Domestic Product	100	122	149	194
Gross Inland Consumption	100	106	110	116
CO_2 emissions	100	97	93	96
Energy intensity	100	87	74	60
Carbon intensity	100	92	84	83
CO_2 emissions / unit of GDP	100	80	62	50

Source: PRIMES.

This reduction in CO_2 emissions takes place against the background of a substantial economic growth in the same period (+94% in 1990 to 2020) and is largely driven by the considerable improvement in energy intensity, especially in the long run. In 2020, one unit of GDP is produced with only half of the CO_2 emissions emitted in 1990. The results obtained from the analysis illustrate that in the context of the "Climate Policy" CAFE Baseline Scenario the EU-25 system more than achieves the Kyoto target in terms of CO_2 emissions (-7.4% from 1990 levels in 2010 compared to a target for greenhouse gases of -5.5%). However, the challenge of climate change, in view of the more stringent cuts that might be required in the long run, remains far from being achieved.

4. Comparison of the "Climate Policy" CAFE Baseline Scenario to the LREM Baseline scenario results

As discussed earlier the "Climate Policy" CAFE Baseline Scenario differs to the LREM Baseline not only because of the assumed existence of climate policy measures, expressed through the introduction of carbon values that act as incentives to energy agents towards reducing CO_2 emissions, but also because of the revision of the macro-economic assumptions, the power generation sector data etc.

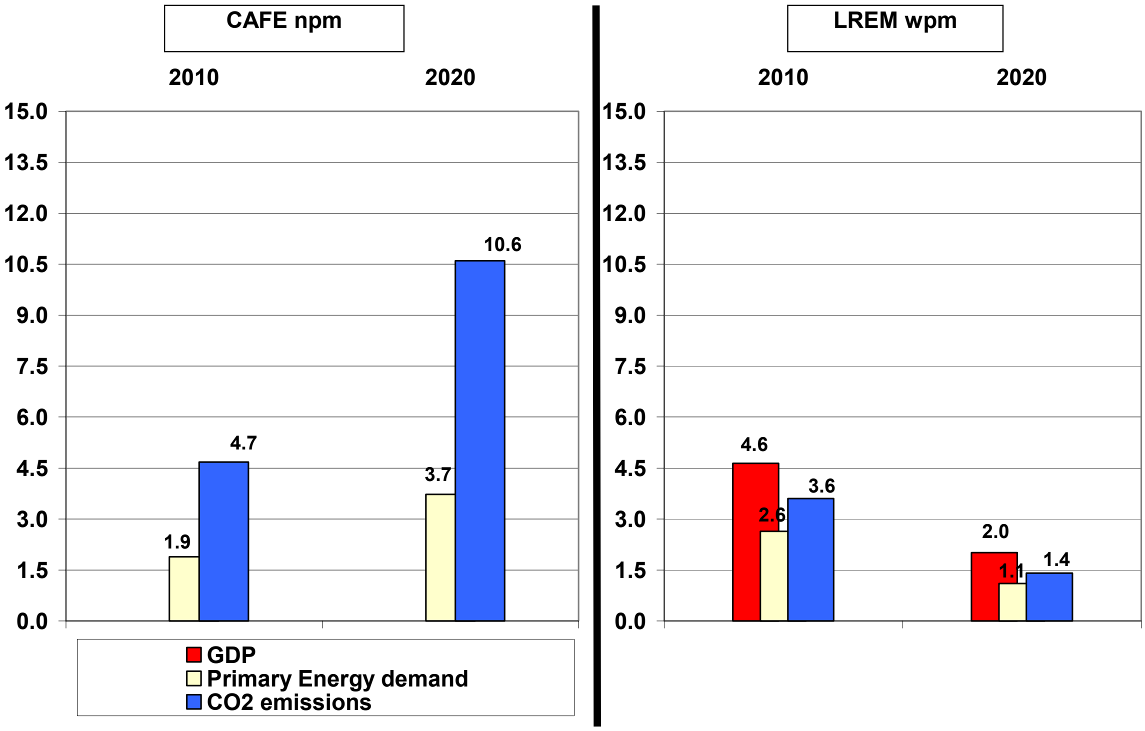
In order to be able to separate the impact that arises from the assumed existence of climate policy initiatives to that of the revision of the data and assumptions used, we present in the following the comparison between the "Climate Policy" CAFE Baseline Scenario (referred to hereafter as the CAFE Baseline) and two alternative scenarios examined in the context of this study, the "Without climate policy" CAFE Baseline Scenario and the "Climate policy" LREM Baseline scenario (referred to hereafter as "CAFE npm" and "LREM wpm" scenarios, respectively).

In the "CAFE npm" scenario the same assumptions are used to those of the CAFE Baseline Scenario but it is assumed that no climate policy incentives are introduced (i.e. carbon values are set to zero). Thus, the comparison between the "CAFE npm" and the CAFE Baseline case helps identify the changes that arise in the EU-25 energy system because of the assumed existence of climate policy measures.

On the other hand, the "LREM wpm" case helps identifying the impact that the revision of assumptions generates on the future evolution of the EU-25 energy system as in this case it is assumed that all assumptions are the same as in the LREM Baseline scenario and in addition the climate policy incentives, as used in the CAFE baseline, are introduced.

Figure 4-1 illustrates the links between changes from CAFE Baseline levels for GDP, energy use and CO_2 emissions over the projection period for the two cases examined. In the "CAFE npm" case, energy demand is projected to increase from CAFE baseline levels by 1.9% and 3.7% in 2010 and 2020 respectively, clearly reflecting the role that climate policy measures play in improving energy intensity in the EU-25 energy system (given that economic activity remains unchanged in the two cases examined, the projected improvement in energy intensity under the "CAFE npm" case is 1.9% lower than in the CAFE Baseline in 2010 and 3.7% lower in 2020). The impact of climate policy measures is even more pronounced on CO_2 emissions as in the "CAFE npm" case they are projected to reach up to 10.6% above CAFE baseline levels in 2020. These differences reflect the effect of a carbon shadow price of € 12 per t of CO_2 and € 20 per t of CO_2 applied in 2010 and 2020, respectively.

Figure 4-1: EU-25 primary energy indicators (% change from Baseline levels)

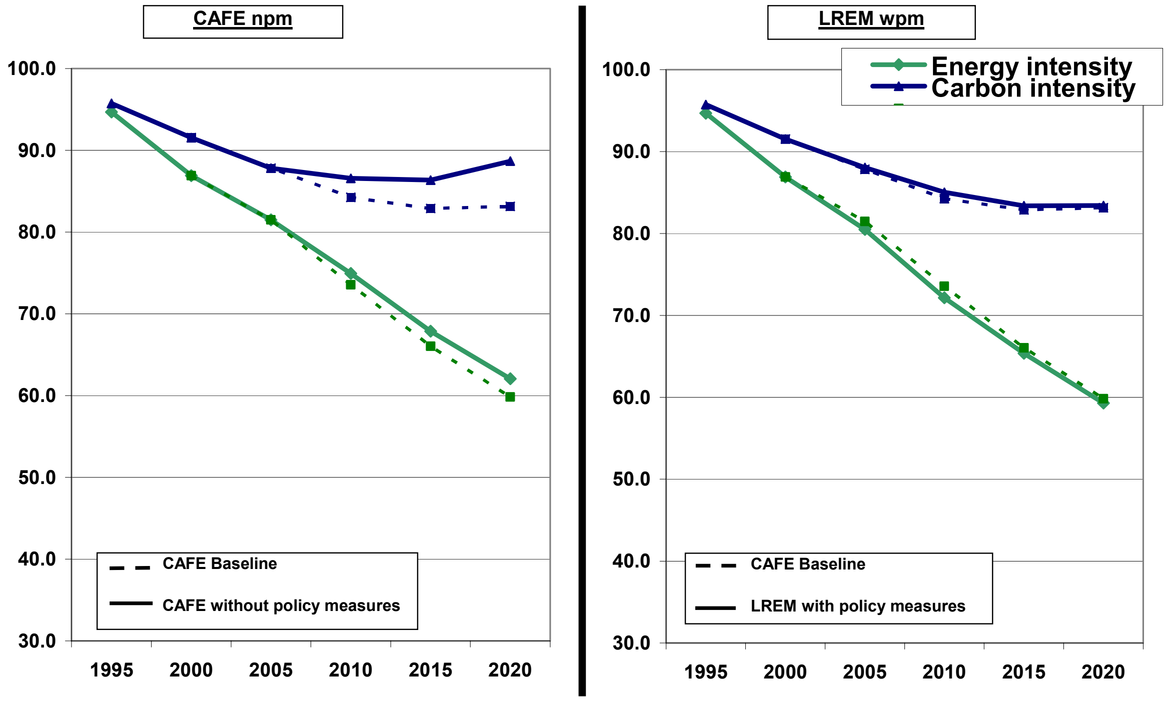


Source: PRIMES.

In the "LREM wpm" case energy needs are projected to grow on top of CAFE Baseline levels by 2.6% in 2010 and 1.1% in 2020. This increase is significantly lower than the corresponding growth in GDP (+4.6% and +2.0% in 2010 and 2020 respectively) implying additional energy intensity gains on top of the CAFE Baseline as a result of the further dematerialisation of the EU-25 economy; but also from the faster adoption of more efficient equipment technologies with accelerated capital stock turnover. As regards CO_2 emissions, they are projected to grow slightly faster than the corresponding growth of energy needs over the projection period, as available options for changes in the fuel mix towards the use of less carbon-intensive fuels become increasingly exploited.

Thus, in the "CAFE npm" case the evolution of the EU-25 energy system is characterized by lower energy intensity gains and a worsening of carbon intensity compared to the CAFE Baseline scenario, a result that clearly illustrates the importance of climate policy incentives introduced in the CAFE Baseline scenario. On the other hand in the "LREM wpm" case trends remain similar to those of the CAFE Baseline scenario, with energy intensity gains becoming slightly more pronounced while carbon intensity exhibits only a limited worsening (see Figure 4-2).

Figure 4-2: Energy and carbon intensity improvement (index, 1990=100; comparison to Baseline)



Source: PRIMES.

The evolution of primary energy needs by energy form in the two alternative cases is illustrated in Table 4-1. In the "CAFE npm" case, besides the growth of energy requirements on top of CAFE Baseline levels, significant changes occur in the fuel mix. Thus, in 2020 solid fuels account for 13.5% of primary energy requirements (from 8.9% in the CAFE Baseline scenario and 18.4% in 2000). This increase occurs to the detriment of all other energy forms and especially renewables and natural gas, the market shares of which reach 8.3% and 32.1% in 2020 (-1.7 and -2.0 percentage points respectively from CAFE Baseline levels).

Table 4-1: Primary Energy Demand in EU-25 (comparison to Baseline)

CAFE npm	Mtoe			*% change from baseline*	
	2000	**2010**	**2020**	**2010**	**2020**
Solid Fuels	303.2	242.0	252.5	16.0	57.6
Liquid Fuels	635.6	630.6	663.7	1.3	2.6
Natural Gas	376.0	491.3	599.9	0.2	-2.4
Nuclear	237.7	241.9	197.3	-0.1	-0.8
Renewable energy forms	96.1	132.4	154.3	-7.0	-14.1
Total	**1651**	**1740**	**1869**	**1.9**	**3.7**
LREM wpm	Mtoe			*% change from baseline*	
	2000	**2010**	**2020**	**2010**	**2020**
Solid Fuels	303.2	218.3	167.7	4.6	4.7
Liquid Fuels	635.6	643.6	654.6	3.4	1.2
Natural Gas	376.0	503.3	613.4	2.6	-0.2
Nuclear	237.7	245.3	210.9	1.3	6.1
Renewable energy forms	96.1	140.2	173.6	-1.5	-3.3
Total	**1651**	**1753**	**1822**	**2.6**	**1.1**

Source: PRIMES.

In the "LREM wpm" case the highest demand growth from Baseline levels among fuels is projected for nuclear energy (+6.1% in 2020) reflecting the different assumptions used as regards the decommissioning schedule for existing nuclear power plants. Solid fuels and liquids are also projected to increase at rates above average (+4.7% and +1.2%

respectively in 2020). Demand for natural gas remains stable whereas renewable energy forms are projected to grow at a slower pace reaching -3.3% relative to CAFE Baseline levels in 2020. As a result of these changes in the fuel mix the market share of renewables reaches 9.5% in 2020 and that of natural gas 33.7% (from 10.0% and 34.1%, respectively, in the CAFE Baseline). The gap generated is largely covered by nuclear energy the market share of which increases from 11.0% in the CAFE Baseline to 11.6% in the "LREM wpm" case and to a less extent solid fuels with a market share of 9.2% in 2020 (+0.3 percentage points compared to the CAFE Baseline).

Table 4-2: Import dependency in EU-25 (comparison to Baseline)

CAFE npm	%			percentage points difference from baseline	
	2000	**2010**	**2020**	**2010**	**2020**
Solid fuels	30.1	38.3	53.0	-1.2	5.9
Liquid fuels	76.6	80.7	85.8	0.2	0.3
Natural gas	49.5	60.5	75.4	-0.1	-0.6
Total	**47.2**	**52.5**	**62.6**	**0.1**	**1.0**
LREM wpm	**%**			**percentage points difference from baseline**	
	2000	**2010**	**2020**	**2010**	**2020**
Solid fuels	30.1	36.3	44.8	-3.2	-2.3
Liquid fuels	76.6	81.0	85.7	0.6	0.2
Natural gas	49.5	60.9	75.9	0.3	-0.1
Total	**47.2**	**52.7**	**61.3**	**0.2**	**-0.3**

Source: PRIMES.

The changes in primary energy requirements in the two cases examined also affect the evolution of import dependency for the EU-25 energy system. Overall import dependency in the "CAFE npm" case is projected to rise at a faster pace compared to CAFE Baseline (reaching +0.1 percentage points higher in 2010, +1.0 in 2020). Import dependency of the EU-25 energy system under the "LREM wpm" case assumptions is projected to exhibit a limited growth on top of CAFE Baseline levels in 2010 (52.7% compared to 52.5%) but grow at a slower pace thereafter reaching 61.3% in 2020 (from 61.6% in the CAFE Baseline scenario) mainly because of the higher exploitation of nuclear energy.

4.1. Impacts on the demand side

The "CAFE npm" case leads to an increase of final energy demand by 1.6% from CAFE Baseline levels in 2010 and 3.0% in 2020 (see Table 4-3). The greatest increase is projected in the tertiary sector (+4.3% from CAFE Baseline levels in 2020), whereas the growth in all other sectors is less pronounced (around +2.8% from CAFE Baseline levels in 2020). However, the picture is quite different in terms of CO_2 emissions. Thus, in the absence of climate change policy incentives the most pronounced increase in CO_2 emissions occurs in industry (+6.7% from CAFE Baseline levels in 2020) followed by the tertiary sector (+6.6%), households (+4.9%) and the transport sector (+2.9%). The limited worsening of carbon intensity in the transport sector indicates that the introduction of climate policy incentives mainly results in improvements in terms of energy intensity whereas changes in the fuel mix remain insignificant as liquid fuels remain the key energy form in the transport sector in both the CAFE Baseline and the "CAFE npm" case. Energy intensity gains are also the key driver for improvements in the tertiary and the households sectors. About 65% of the projected increase in CO_2 emissions in 2020 under the "CAFE npm" case assumptions in the tertiary sector and 60% in the households sector come from an increase in energy requirements, the rest from changes in the fuel mix. It is only in industry that the projected increase in CO_2

emissions for the "CAFE npm" case is driven by the worsening of carbon intensity in the sector (accounting for close to 60% of the overall increase in emissions in 2020).

Table 4-3: Final Energy Demand and CO_2 emissions by Sector in the EU-25 under "CAFE npm" case assumptions

	Mtoe			% change from baseline	
	2000	**2010**	**2020**	**2010**	**2020**
Industry	309.1	334.2	370.6	1.3	2.8
Tertiary	154.2	167.9	192.0	3.7	4.3
Households	279.1	302.8	326.9	1.5	2.8
Transports	332.0	376.7	421.9	1.1	2.8
Total	**1074**	**1182**	**1311**	**1.6**	**3.0**
	Mt CO2 emissions			***% change from baseline***	
	2000	**2010**	**2020**	**2010**	**2020**
Industry	605.7	544.2	560.1	4.4	6.7
Tertiary	236.7	233.2	239.9	6.0	6.6
Households	462.6	473.5	491.0	3.0	4.9
Transports	967.5	1079.4	1197.8	1.1	2.9
Total	**2272**	**2330**	**2489**	**2.7**	**4.5**

Source: PRIMES.

In the "LREM wpm" case, final energy demand in the EU is projected to grow at rates slightly above those of the CAFE Baseline scenario in the short run (+2.3% in 2010) but slowdown thereafter (+0.5% in 2020) (see Table 4-4). This result largely reflects the different economic growth assumptions introduced in the two cases examined. This is also the key driver for the different evolution of energy requirements at the sectoral level. Industrial energy demand is 0.8% lower in 2020 under the "LREM wpm" case assumptions than in the "CAFE Baseline" reflecting the more pronounced shift towards non-energy intensive industries assumed in the "LREM wpm" case. This is also reflected on the projected evolution of CO_2 emissions in industry (-3.0% from CAFE Baseline levels in 2020) as non-energy intensive industries mainly consume electricity and co-generated steam allowing for additional carbon intensity gains.

Table 4-4: Final Energy Demand and CO_2 emissions by Sector in the EU-25 under "LREM wpm" case assumptions

	Mtoe			% change from baseline	
	2000	**2010**	**2020**	**2010**	**2020**
Industry	309.1	334.5	357.5	1.4	-0.8
Tertiary	154.2	167.5	186.3	3.5	1.3
Households	279.1	303.9	319.8	1.9	0.6
Transports	332.0	383.3	415.3	2.9	1.2
Total	**1074**	**1189**	**1279**	**2.3**	**0.5**
	Mt CO2 emissions			***% change from baseline***	
	2000	**2010**	**2020**	**2010**	**2020**
Industry	605.7	521.4	509.2	0.0	-3.0
Tertiary	236.7	226.0	225.4	2.7	0.2
Households	462.6	468.2	472.2	1.8	0.9
Transports	967.5	1099.2	1179.2	3.0	1.3
Total	**2272**	**2315**	**2386**	**2.0**	**0.2**

Source: PRIMES.

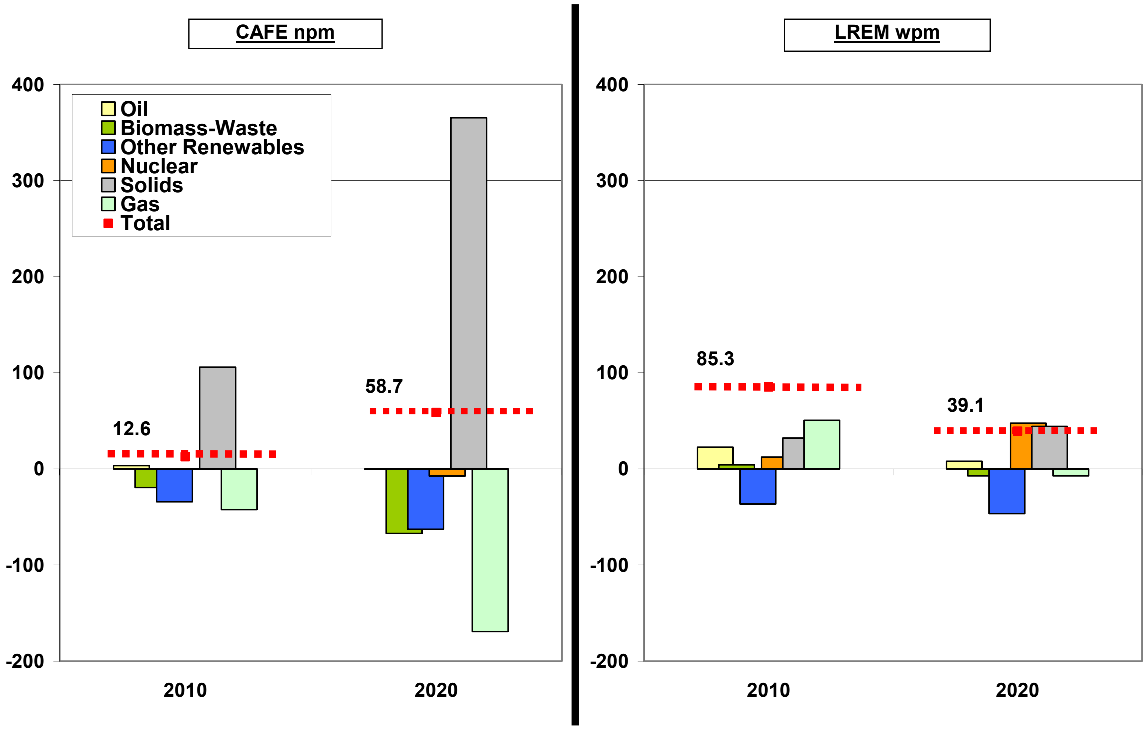
Energy requirements in the other sectors of the demand side are projected to be higher than in the CAFE Baseline scenario reflecting the more pronounced economic growth occurring under the "LREM wpm" scenario assumptions. CO_2 emissions also increase with a worsening of carbon intensity taking place only in the households and the transport sectors, while in the tertiary sector the further shift towards electricity that takes place limits the overall increase of emissions to levels well below those corresponding to energy requirements.

4.2. Impacts on electricity and steam generation

Changes in electricity demand follow similar trends in both cases examined exhibiting a higher growth compared to the CAFE Baseline scenario. However, because of the different assumptions for the future evolution of the EU-25 economy and climate policy incentives in the "CAFE npm" case, electricity demand exhibits a limited growth on top of CAFE Baseline levels in the short term (+0.3% in 2010) which is more pronounced in the long run (+1.3% in 2020). In the "LREM wpm" case the increase is more pronounced in 2010, reaching +2.6% from CAFE Baseline levels in 2010, and decelerates thereafter to reach +0.9% in 2020.

In the "CAFE npm" case, the absence of climate policy incentives leads to a strong increase in electricity generation from solid fuels (more than 6 times higher than the corresponding increase in total electricity generation for 2020) that take place to the detriment of all other energy forms (see Figure 4-3). In 2020, the most pronounced difference in absolute terms occurs for natural gas (-169 TWh or -9.8% from CAFE Baseline levels) followed by biomass-waste (-67 TWh or -43%) and intermittent renewable energy forms (-63 TWh or -8.9%). As a result of these changes the share of renewable energy forms (including waste) in total electricity generation in 2020 is limited to 18.7% (3.7 percentage points below CAFE Baseline levels) while that of electricity generation from solid fuels reaches 20.8% from 11.7% in the CAFE Baseline scenario.

Figure 4-3: Changes in electricity generation by energy form in EU-25 (diff. from Baseline in TWh)



Source: PRIMES.

In the "LREM wpm" case, changes in the power generation sector are less pronounced as they are mainly driven by higher economic growth and changes in assumptions for the evolution of the power generation sector. Thus, in 2020 an increase on top of CAFE Baseline levels is projected for electricity generated from nuclear energy (+48 TWh or +6.1%) and solid fuels (+44 TWh or +9.8%) occurring to the detriment of intermittent renewables (-46.6 TWh or -6.7%). The increase in the use of nuclear energy almost counterbalances the decline for renewables with the share of non-fossil fuels in power generation reaching 41.9% in 2020 from 42.5% in the CAFE Baseline scenario (in contrast to the "CAFE npm" case in which this share is limited to 38.3%).

The projected slowdown in the deployment of intermittent renewable energy sources (mainly wind turbines) in both cases examined, results in a decline of overall installed capacity from CAFE Baseline levels (see Table 4-5). Total installed generating capacity in the "CAFE npm" case is projected to be some 12.4 GW lower than CAFE Baseline levels in 2010 and 8.3 GW in 2020. In the absence of climate policy incentives installed capacities for conventional thermal power plants but also supercritical polyvalent units increase from CAFE Baseline levels (+18.6 GW and +20.9 GW, respectively in 2020), an increase that takes place to the detriment of gas turbine combined cycle plants (-25.5 GW) and wind turbines (-24.0 GW).

Table 4-5: Installed capacity by plant type in the EU-25 (comparison to Baseline)

CAFE npm	**GW installed**			***change from baseline (in GW)***	
	2000	**2010**	**2020**	**2010**	**2020**
Nuclear	140.3	131.6	102.0	0.0	-3.2
Hydro	96.2	105.3	110.4	-0.7	-2.0
Wind	12.8	77.3	119.9	-14.8	-24.0
Other renewables	0.2	0.5	0.6	0.0	-0.5
Conventional thermal	335.6	259.5	172.8	0.8	18.6
Advanced coal	0.0	0.3	1.8	-0.2	0.7
Supercritical polyvalent	0.0	0.3	55.9	-0.3	20.9
Gas turbines CC	47.4	170.8	320.8	-0.5	-25.5
Small gas turbines	22.8	38.6	66.5	3.3	6.7
Geothermal	1.0	1.2	1.2	0.0	-0.1
Total	**656**	**785**	**952**	**-12.4**	**-8.3**
of which CHP	***103***	***132***	***172***	***-0.2***	***3.1***
LREM wpm	**GW installed**			***change from baseline (in GW)***	
	2000	**2010**	**2020**	**2010**	**2020**
Nuclear	140.3	129.8	110.9	-1.8	5.7
Hydro	96.2	105.1	111.5	-0.9	-0.8
Wind	12.8	78.7	124.4	-13.3	-19.5
Other renewables	0.2	0.5	0.6	0.0	-0.4
Conventional thermal	335.6	266.3	159.2	7.6	5.0
Advanced coal	0.0	0.6	1.0	0.2	-0.1
Supercritical polyvalent	0.0	1.7	40.0	1.1	5.0
Gas turbines CC	47.4	173.1	346.3	1.7	0.1
Small gas turbines	22.8	31.4	58.4	-3.9	-1.4
Geothermal	1.0	1.2	1.4	0.0	0.1
Total	**656**	**788**	**954**	**-9.4**	**-6.4**
of which CHP	***103***	***132***	***163***	***-0.6***	***-6.4***

Source: PRIMES.

In the "LREM wpm" case, changes in total installed capacity are less pronounced (-9.4 GW in 2010 and -6.4 GW in 2020) with the most significant decline occurring for wind turbines (124.4 GW in 2020 from 144.0 GW in the CAFE Baseline scenario). As in the "CAFE npm" case an increase is projected for conventional thermal and supercritical polyvalent power plant capacities, while, because of the different assumptions introduced as regards nuclear decommissioning, the installed capacity of nuclear power plants in the EU-25 power generation sector is projected to be some 5.7 GW higher in 2020 than in the CAFE Baseline scenario.

Fuel input trends in electricity and steam generation for the two cases examined are illustrated in Table 4-6. In the "CAFE npm" case, with overall fuel input for electricity and steam generation increasing by +5.5% from CAFE Baseline levels in 2020, the absence of climate policy incentives acts to the detriment of natural gas and biomass-waste and in favour of solid fuels. In absolute terms the most pronounced difference is projected for natural gas (-26.5 Mtoe from CAFE Baseline levels in 2020) followed by biomass, the consumption of which is limited to less than 60% the corresponding one in the CAFE Baseline scenario. Solid fuels act not only in covering the gap generated because of the lower use of natural gas and biomass but also the additional energy requirements of the power generation sector. Thus, in 2020 some 85 Mtoe of solid fuels, on top of those projected under CAFE Baseline assumptions, are projected to be consumed in the EU-25 power generation sector. This shift, in combination to the lower exploitation of intermittent renewable energy forms, is also reflected in the evolution of CO_2 emissions in the EU-25 power generation sector, which are projected to be almost 24% higher than in the CAFE Baseline scenario by 2020.

Table 4-6: Fuel input in electricity and steam generation in the EU-25 (comparison to Baseline)

CAFE npm	**Mtoe**			***% change from baseline***	
	2000	**2010**	**2020**	**2010**	**2020**
Solids	217.4	175.0	189.0	19.9	82.4
Oil products	52.4	27.3	21.4	4.2	1.3
Gas	131.7	195.3	268.2	-3.4	-9.0
Biomass	12.7	18.2	21.7	-14.4	-42.1
Waste	19.3	24.9	27.3	-11.5	-11.7
Nuclear energy	237.7	241.9	197.3	-0.1	-0.8
Geothermal heat	3.0	3.4	3.4	-0.4	-5.5
Total	**674**	**686**	**728**	**2.5**	**5.5**
Mt CO2 emitted	***1355***	***1249***	***1453***	***9.2***	***23.9***
LREM wpm	**Mtoe**			***% change from baseline***	
	2000	**2010**	**2020**	**2010**	**2020**
Solids	217.4	155.9	114.1	6.8	10.1
Oil products	52.4	31.5	22.9	20.0	8.1
Gas	131.7	208.7	291.9	3.2	-1.0
Biomass	12.7	21.5	34.7	0.8	-7.6
Waste	19.3	28.1	31.2	0.1	1.0
Nuclear energy	237.7	245.3	210.9	1.3	6.1
Geothermal heat	3.0	3.5	3.7	2.2	3.3
Total	**674**	**694**	**709**	**3.8**	**2.7**
Mt CO2 emitted	***1355***	***1217***	***1216***	***6.4***	***3.7***

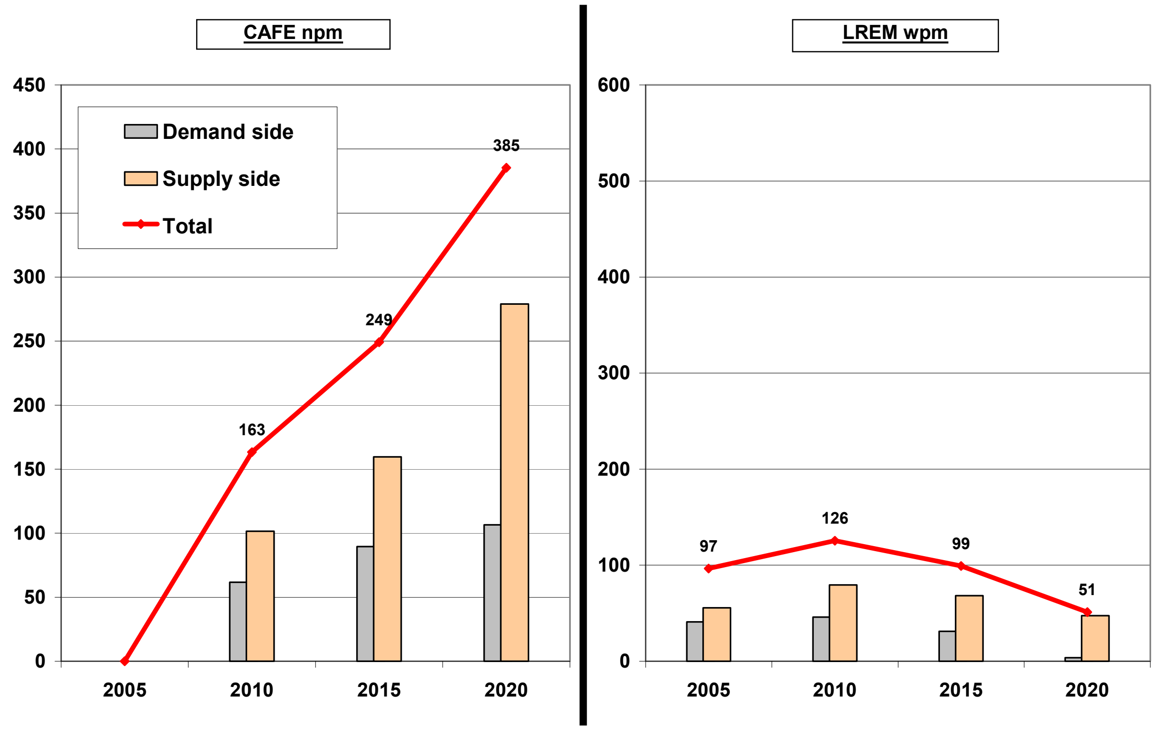
Source: PRIMES.

In the "LREM wpm" case, overall energy requirements in the power generation sector increase by +2.7% from CAFE Baseline levels in 2020. Consumption of solid fuels is projected to be higher than in the CAFE Baseline by +10.1% in 2020, whereas an increase (reflecting the different assumptions used in the two scenarios) is also projected for nuclear energy (+6.1% in 2020). The energy form that is most affected is biomass (-7.6% in 2020) whereas a limited decline is also projected for natural gas (-1.0% in 2020). However, the higher exploitation of nuclear energy largely counterbalances the smaller use of biomass and intermittent renewable energy forms in the "LREM wpm" case, with CO_2 emissions in the power generation sector increasing by 3.7% from CAFE Baseline levels in 2020.

4.3. Impacts on CO_2 emissions

The impact of two cases examined on the projected evolution of CO_2 emissions for the EU-25 energy system is illustrated in Figure 4-4. The absence of climate policy incentives leads to a significant growth of CO_2 emissions compared to the CAFE Baseline (+385 Mt CO_2 or +10.6% in 2020). Changes in the power generation sector are the key driver for this growth (accounting for 62% of overall CO_2 emissions growth in 2010 and 72% in 2020), reflecting the much higher flexibility of the sector to the introduction of climate policy incentives.

Figure 4-4: Changes in CO_2 emissions in EU-25 (diff. from Baseline in Mt CO_2)



Source: PRIMES.

In the "LREM wpm" case, CO_2 emissions growth on top of CAFE Baseline levels exhibits a declining trend over the projection period as the impact of changes in macroeconomic assumptions gradually becomes less pronounced. Thus, whereas in 2010 CO_2 emissions are projected to rise by 126 Mt CO_2 (+3.6%) from CAFE Baseline levels, this increase is limited to 51 Mt CO_2 (+1.4%) by 2020, implying a slower pace of growth compared to the CAFE Baseline scenario between 2010 and 2020. As in the "CAFE npm" case changes in the supply side are the key driver for the projected change in CO_2 emissions (accounting for 63% of overall emissions growth in 2010 and 93% in 2020).

The results obtained from the analysis clearly illustrate the predominant role that the introduction of climate policy incentives plays on the future evolution of the EU-25 energy system as the "LREM wpm" case is characterised by only limited changes compared to the CAFE Baseline scenario whereas these changes become very significant in the "CAFE npm" case.

5. "Illustrative climate" scenario results for EU-25 (beyond Kyoto)

The "illustrative climate" scenario assumes that higher carbon prices apply to the EU-25 energy system beyond 2010 (45 € per t of CO_2 in 2015, reaching 90 € per t of CO_2 in 2020, compared to 16 € per t of CO_2 in 2015 and 20 € per t of CO_2 in 2020 in the CAFE Baseline scenario). The stronger climate policy incentives addressed to the agents, producers and consumers, of the energy system are clearly reflected in the results obtained with EU-25 CO_2 emissions reaching close to 20 percent below 1990 levels by 2020, compared to -3.6% in the CAFE Baseline scenario.

At the aggregate level of analysis, the economic system has two means of responding to the introduction of higher climate policy incentives while maintaining the same level of GDP. Either it can reduce the level of energy used per unit of GDP (the energy intensity) or it can change the fuel mix in order to reduce the carbon intensity of its energy sub-system. The division of the system's response between these two effects is an important indication of where most of the flexibility in the system can be found. A reduction in the carbon intensity of the energy system indicates that, to a certain degree, substitution opportunities among fuels are more cost effective than substitution of energy by other goods (leading to energy intensity improvements).

These two effects for the EU-25 as a whole can be seen in Table 5-1. In the presence of higher climate policy incentives energy requirements are projected to be 7.4% lower in 2020 compared to the CAFE Baseline scenario, a reduction equivalent to the improvement in energy intensity, as GDP remains unchanged from CAFE Baseline levels. The corresponding reduction in terms of CO_2 emissions in 2020 reaches -16.2%, with the contribution of changes in the fuel mix accounting for 54% of the overall emissions reduction achieved. Thus, besides the overall decline of primary energy requirements in the "Illustrative climate" case, the EU-25 energy system is also characterised by a significant fuel switching away from high carbon fuels such as coal and lignite to low carbon fuels, such as natural gas, and carbon free fuels, such as renewables and nuclear.

Table 5-1: Primary energy demand in the EU-25 in the "Illustrative climate" case

	Mtoe			% change from baseline	
	2000	**2010**	**2020**	**2010**	**2020**
Solid Fuels	303	209	74	0.0	-53.7
Liquid Fuels	636	622	603	0.0	-6.8
Natural Gas	376	490	565	0.0	-8.1
Nuclear	238	242	194	0.0	-2.3
Renewable energy forms	96	142	230	0.0	28.2
Total	**1651**	**1708**	**1669**	**0.0**	**-7.4**
Mt CO2 emitted	**3665**	**3489**	**3047**	**0.0**	**-16.2**

Source: PRIMES.

Solid fuels, the most carbon intensive of all the primary fuels, become an almost obsolete energy form with their market share limited in 2020 to 4.4% of overall primary energy needs (compared 8.9% in 2020 under CAFE Baseline assumptions and to 18.4% in 2000). Demand for natural gas (-8.1% from CAFE Baseline levels in 2020) declines not only because of the overall fall in energy consumption but also because their use is replaced by less carbon-intensive fuels. Thus in 2020 natural gas accounts for 33.9% of primary energy needs (0.2 percentage points less than in the CAFE Baseline scenario). The negative effect on liquid fuels (-6.8% from CAFE Baseline levels in 2020) is due mostly to the reduction in overall demand rather than to substitution, reflecting the limited potential for changes in the fuel mix in the transport sector (the main consumer of liquid fuels even under Baseline assumptions). In the "Illustrative climate" case, liquid fuels account for 36.1% of primary energy needs in 2020 from 35.9% in the CAFE Baseline scenario. The overall share of fossil fuels in the EU-25 energy system reaches 74.5% in 2020 compared to 78.9% in the CAFE Baseline, clearly reflecting the strong shift towards the use of carbon free energy forms in the presence of strong climate policies incentives.

The major role that renewable energy forms are called upon to play for the EU-25 energy system in reducing CO_2 emissions is clearly illustrated in their market share in total primary energy needs which is projected to reach 13.8% in 2020 (+3.8 percentage points above CAFE Baseline levels) while the contribution of nuclear energy also increases in terms market shares accounting for 11.6% of primary energy needs in 2020 (+0.6 percentage points from CAFE Baseline levels).

Besides the projected reduction in CO_2 emissions, the decline of primary energy needs, combined with the projected shifts towards the use of indigenous energy sources (such as renewable energy forms and nuclear energy), has a significant impact on the evolution of EU-25 import dependency which is limited in the "Illustrative climate" scenario to 58.5% in 2020 compared to 61.6% in the CAFE Baseline scenario.

5.1. Final energy demand

The impact of the introduction of stronger climate policy incentives in the demand side is somewhat different from the overall reaction of the EU-25 energy system. As illustrated in Table 5-2, energy requirements in the demand side decline in 2020 by -8.1% from CAFE Baseline levels (a reduction slightly higher to that of overall primary energy needs by -7.4%) whereas CO_2 emissions related to final energy demand are projected to fall -15.0% in 2020 from CAFE Baseline compared to an overall reduction of CO_2 emissions in the EU-25 energy system by -16.2%. Thus, the response of the demand side involves higher energy intensity gains, which account for close to 54% of the CO_2 emissions reduction achieved compared to 46% at the level of the overall energy system.

Table 5-2: Final energy demand in the EU-25 in the "Illustrative climate" case

	Mtoe			*% change from baseline*	
	2000	**2010**	**2020**	**2010**	**2020**
Industry	309.1	329.9	338.8	0.0	-6.0
Tertiary	154.2	161.8	164.0	0.0	-10.9
Households	279.1	298.2	284.1	0.0	-10.6
Transports	332.0	372.5	382.8	0.0	-6.7
Total	**1074**	**1162**	**1170**	**0.0**	**-8.1**
	Mt CO2 emissions			***% change from baseline***	
	2000	**2010**	**2020**	**2010**	**2020**
Industry	605.7	521.5	446.4	0.0	-14.9
Tertiary	236.7	220.1	186.7	0.0	-17.0
Households	462.6	459.9	402.9	0.0	-13.9
Transports	967.5	1067.2	1084.0	0.0	-6.9
Total	**2272**	**2269**	**2120**	**-4.5**	**-15.0**

Source: PRIMES.

The tertiary sector is the most responsive to the introduction of the stronger climate policy incentives, both in terms of energy requirements (declining by -10.9% from CAFE Baseline levels in 2020) and CO_2 emissions (-14.9%). Changes in consumers' behaviour and the adoption of more efficient technologies are the key drivers for the projected energy intensity gains (accounting for 64% of projected CO_2 emissions reduction in 2020). Shifts in the fuel mix towards less carbon intensive energy forms allow for the projected improvement in carbon intensity. The same drivers, but with a less pronounced effect, act for energy and carbon intensity gains achieved in households with energy requirements in the "Illustrative climate" case declining by -10.6% below CAFE Baseline levels in 2020 and reduction in CO_2 emissions reaching -13.9%.

In the transport sector consumers react to the introduction of stronger climate policy incentives by reducing overall transport activity, shifting towards less energy-intensive transport modes, and adopting more efficient vehicle technologies. These changes result in a reduction of energy requirements and CO_2 emissions in the sector by -6.7% and -6.9% respectively from CAFE Baseline levels in 2020. The less pronounced reduction of energy needs in the transport sector compared to that projected for the other demand side sectors, is largely due to the pre-existence of high consumption taxes that reduce the effect of stronger climate policy incentives. Furthermore, carbon intensity improvements in the sector are very limited as no new cost-effective fuels are expected to enter the transportation sector in any significant way in the near future without strong specific policies.[10]

[10] The use of low or zero carbon fuels in transportation implies the massive development of infrastructure for new fuel cycles, like hydrogen and methanol originating from biomass, or fossil fuels with CO_2 sequestration.

Industry also exhibits inertia to the introduction of stronger climate policy incentives with energy use in industrial sectors declining by -6.0% from CAFE Baseline levels in 2020, a result that is largely due to the significant restructuring and energy intensity gains that already occur in industrial sectors under CAFE Baseline assumptions, but also by the assumption that the sectoral value added of industrial sectors is not affected in comparison to CAFE Baseline. On the other hand CO_2 emissions reduction in industry reach -14.9% in 2020, with carbon intensity gains accounting for some 60% of the emissions reduction achieved. The significant changes in the fuel mix towards the use of less carbon intensive fuels are largely explained by the fact that industry experiences the sharpest variations in terms of energy costs because of the relatively low pre-existing taxation of energy products in this sector.

Carbon intensity gains on the demand side of the EU-25 energy system in the "Illustrated climate" case arise from changes in the fuel mix towards the use of carbon free energy forms. Demand for biomass is projected to grow on top of CAFE Baseline levels (+4.7% or + 1.5 Mtoe in 2020) whereas co-generated steam demand remains unchanged to the CAFE Baseline scenario (-0.2% or -0.2 Mtoe). Furthermore, electricity demand decreases much less than total final energy demand (-4.7% for electricity versus -8.4% for total final energy demand) as the impact of the imposition of carbon values on the price of electricity is comparatively lower to that for fossil fuels. This is due to the various other cost components included in the electricity price in addition to fossil fuel costs. The comparatively low impact on electricity prices of the carbon constraints also stems from the adaptation measures in power generation undertaken in response to the additional costs arising from carbon values on fossil fuels (see below). Furthermore it should be recalled that CO_2 emissions for the production of electricity and co-generated steam are accounted for on the supply side. On the contrary, demand for fossil fuels exhibits a strong decline from CAFE Baseline levels. Solid fuels decrease -36.3% (or -11.5 Mtoe) in 2010. In absolute terms the strongest decline in 2020 is projected for natural gas and liquid fuels (-40 Mtoe and -39 Mtoe respectively from CAFE Baseline levels, corresponding to a reduction of -12.8% and -7.6% in percentage terms).

The higher reduction rates projected for fossil fuels (with solids and natural gas demand declining at rates above average and that for liquids slightly below average) leads to the projected improvement of carbon intensity in the demand side under the "Illustrative climate" case assumptions. In 2020, CO_2 emissions reduction from the demand side accounts for 44.6% of total CO_2 emissions reduction achieved in the EU-25 energy system.

5.2. Impacts on electricity and steam generation

The power and steam generation sector of the EU-25 energy system appears to be that which can adjust in the most cost-effective way to the introduction of higher climate policy incentives. The high flexibility of the power sector is clearly illustrated in Table 5-3. With electricity generation declining in 2020 by -4.8% from CAFE Baseline levels due to changes occurring on the demand side, the decline in fossil fuels input reaches -9.7% as higher costs for fossil fuel inputs due to high carbon values lead to strong shifts towards the use of nuclear and intermittent renewables. These shifts, combined with higher exploitation of the biomass-waste potential in thermal power plants, allow for a more pronounced decline of CO_2 emissions in the power generation sector (-28.9% below CAFE Baseline in 2020).

Table 5-3: Power generation in the EU-25 in the "Kyoto forever" case

				% change from baseline	
	2000	**2010**	**2020**	**2010**	**2020**
Fossil fuel input (Mtoe)	**384.6**	**377.7**	**399.2**	**0.0**	**-9.7**
Electricity generated (TWh)	**2897.9**	**3315.9**	**3672.5**	**0.0**	**-4.8**
Nuclear	921.2	940.3	759.7	0.0	-2.2
Thermal (incl. biomass/waste)	1617.2	1811.6	2137.4	0.0	-10.2
Solids	911.7	584.6	141.2	0.0	-68.6
Liquids	175.1	59.9	32.9	0.0	-28.7
Natural gas	467.1	1062.4	1620.0	0.0	-5.9
Biomass-waste	58.2	98.6	335.1	0.0	115.5
Geothermal heat	5.2	5.9	8.1	0.0	28.7
Hydro & Intermittent renewables	359.5	564.0	775.5	0.0	10.7
Hydro	337.1	352.1	383.1	0.0	2.8
Wind energy	22.4	211.4	384.9	0.0	17.9
Other renewables	0.0	0.5	7.6	0.0	405.4
CO2 emissions (Mt of CO2)	**1193**	**1063**	**783**	**0.0**	**-28.9**

Source: PRIMES.

Solid fuels are most affected by the introduction of stronger climate policy incentives. In 2020, electricity generation from solid fuels declines by close to -70% from CAFE Baseline levels, a decline that in absolute terms is 1.7 times higher than the corresponding decline of overall electricity production (-309 TWh versus -184 TWh). In 2020 electricity generation from solid fuels accounts for just 3.8% of total electricity production, compared to 11.7% under CAFE Baseline assumptions. Electricity generation from natural gas is also projected to decline at rates above average (-5.9% or -102 TWh from CAFE Baseline levels in 2020) while the highest growth both in absolute (+180 TWh in 2020) and percentage terms (+116%) is projected for biomass-waste. Electricity generation from hydro and intermittent renewable energy sources increases by +10.7% (or +75 TWh) above CAFE Baseline levels in 2020, mainly driven by the higher exploitation of wind potential in the EU-25 energy system. Nuclear power production is projected to decline at rates below average (-2.2% versus -4.8% in 2020) further contributing to an increase of share of carbon free energy forms in overall electricity generation. The share of non-fossil fuels in electricity generation under the "Illustrated climate" case assumptions reaches 51.1% in 2020 compared to 42.5% in the CAFE Baseline scenario, with renewable energy forms (including waste) accounting for 30.5% (+8.1 percentage points from CAFE Baseline levels).

These changes are also reflected in total installed capacity (see Table 5-4) with the combined share of hydro, wind and solar photovoltaic reaching 30.0% of total installed capacity in 2020. The nuclear share amounts to 11.0% in 2020. Supercritical polyvalent technology is affected most by the stronger climate policy incentives towards reducing CO_2 emission whereas a growth above CAFE Baseline levels is projected for advanced coal power plants due to their potential for using biomass as an input fuel. For the same reason capacity of conventional thermal power plants grows well above CAFE Baseline levels (+25 GW) in 2020. Gas turbine combined cycle power plant capacity exhibits a slight decline from CAFE Baseline levels in 2020, whereas fuel cells units that reform natural gas into hydrogen on site make some inroads in the EU-25 power sector with a capacity that reaches 2.5 GW in 2020 (from zero in the CAFE Baseline scenario).

Table 5-4: Installed capacity by plant type in EU-25 in the "Kyoto forever" case

	GW installed			change from baseline (in GW)	
	2000	**2010**	**2020**	**2010**	**2020**
Nuclear	140.3	131.6	107.8	0.0	2.6
Hydro	96.2	106.0	117.6	0.0	5.3
Wind	12.8	92.1	170.9	0.0	27.0
Other renewables	0.2	0.5	4.6	0.0	3.6
Conventional thermal	335.6	258.7	178.8	0.0	24.6
Advanced coal	0.0	0.5	8.9	0.0	7.8
Supercritical polyvalent	0.0	0.6	9.3	0.0	-25.7
Gas turbines CC	47.4	171.4	328.2	0.0	-18.1
Small gas turbines	22.8	35.3	44.7	0.0	-15.1
Fuel cells	0.0	0.0	2.5	0.0	2.5
Geothermal	1.0	1.2	1.8	0.0	0.5
Total	**656**	**798**	**975**	**0.0**	**14.9**
of which CHP	***103***	***133***	***184***	***0.0***	***14.8***

Source: PRIMES.

Fuel input for power and steam generation declines by -7.2% from CAFE Baseline levels in 2020 (see Table 5-5). The consumption of solid and liquid fuels declines markedly from Baseline levels, whereas the use of natural gas and nuclear energy declines at rates below average. On the contrary, biomass consumption in electricity and steam generation more than doubles in 2020 from CAFE Baseline levels, while a less pronounced growth is also projected for waste and geothermal heat.

Table 5-5: Fuel input in electricity and steam generation in EU-25 in the "Kyoto forever" case

	Mtoe			% change from baseline	
	2000	**2010**	**2020**	**2010**	**2020**
Solids	217.4	146.0	32.2	0.0	-68.9
Oil products	52.4	26.2	18.1	0.0	-14.4
Gas	131.7	202.1	280.8	0.0	-4.7
Biomass	12.7	21.3	75.6	0.0	101.5
Waste	19.3	28.1	34.9	0.0	12.9
Nuclear energy	237.7	242.1	194.3	0.0	-2.3
Geothermal heat	3.0	3.4	4.7	0.0	28.7
Total	**674**	**669**	**641**	**0.0**	**-7.2**
Mt CO2 emitted	***1355***	***1144***	***849***	***0.0***	***-27.6***

Source: PRIMES.

The clear shift towards the use of less carbon intensive and carbon free energy forms in the "Illustrative climate" case leads to a significant improvement of carbon intensity in electricity and steam generation. CO_2 emissions from electricity and steam generation (including emissions from industrial boilers and district heating) are limited to 72.4% of those projected under CAFE Baseline assumptions in 2020, exhibiting a strong decline between 2010 and 2020 (-25.8%) compared to an increase in the same period by 2.5% that occurred in the CAFE Baseline scenario.

5.3. Impacts on CO_2 emissions

As already discussed, changes on the supply side are the key driver for the achieved CO_2 emissions reduction in the "Illustrative climate" scenario in comparison to the CAFE Baseline scenario. In 2020, overall CO_2 emissions reduction reaches -588 Mt CO_2, with reductions from the supply side accounting for 55.4% of them, clearly reflecting the large potential existing in the power generation sector to reduce CO_2 emissions due to the wide range of options for responding to the introduction of CO_2 emissions reduction constraints.

Higher climate policy incentives, expressed through higher carbon values that reach 90 € per t of CO_2 in 2020 compared to 20 € per t of CO_2 in the CAFE Baseline scenario, allow for a declining trend for CO_2 emissions over the projection period. In 2020, the projected CO_2 emissions in the EU-25 energy system are limited to 80.8% of those observed in 1990, compared to 92.6% in 2010 and 97.2% in 2000. It should be reminded here that in the CAFE Baseline scenario, CO_2 emissions are projected to grow slightly from 2010 onwards reaching at 96.4% of 1990 levels by 2020.

Another interesting finding of the analysis concerns the pace of growth of carbon values compared to the achieved reduction in CO_2 emissions between the different time periods. In the CAFE Baseline scenario a marginal abatement cost of 12 € per t of CO_2 leads to a reduction of emissions by 163 Mt CO_2 in comparison to the "CAFE npm" case. In 2020, with the marginal abatement cost rising to 20 € per t of CO_2 (+67% compared to the carbon value applied in 2010) the corresponding reduction in CO_2 emissions reaches 385 Mt CO_2 (some 136% more compared to that in 2010). This feature reflects the fact that, as a result of achieving a target in a specific time period, the energy system adjusts through improvements in energy and carbon intensity In turn this allows for an easier achievement of targets faced in the future. In addition to the above, as we move further into the future, then technological improvements make emission reductions relatively easier than is true with current technologies. The above mentioned trend is also evident in the "Illustrative climate" case with a reduction of CO_2 emissions close to five times higher (in comparison to the "CAFE npm" case) that achieved in 2010, being achieved with a carbon value 3.5 times higher in 2020 than that applied in 2010. However, in relative terms the reduction in CO_2 emissions achieved in the "Illustrative climate" case in comparison to the growth of carbon values is less pronounced compared to that in the CAFE Baseline scenario, reflecting the increasing exploitation of technological options over time as well as the inherent limitations of the energy system as regards more profound changes in the fuel mix when deeper cuts in CO_2 emissions need to be met.