
The European energy outlook to 2010 and 2030

Pantelis Capros and Leonidas Mantzos

Department of Electrical Engineering, National Technical University of Athens, 9 Iroon Politechniou Str., Zografou Campus, GR-157 73, Athens, Greece. E-mail: kapros@central.ntua.gr

Abstract: This paper presents a consistent EU energy and energy related emissions outlook for the period to 2030. The baseline scenario for the EU was developed using the PRIMES model. The first section presents the key energy features of the baseline outlook of the European energy system. The second section deals with the role of technology progress in the demand and the supply side. Emphasis is given to the role of technological improvement both in the short and the long run. Finally, the paper concludes with the key messages of the outlook.

Keywords: Energy analysis; energy forecasting; energy market; environment; European Union.

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Biographical notes: Pantelis Capros is a Professor of Energy Economics and Operation Research at the Department of Electrical and Computer Engineering of the National Technical University of Athens. He is a member of the Board of Directors of the Greek Public Corporation. Prof. Capros holds an engineering degree from NTUA, 3 DEAs in Economics, Informatics and Operations Research from ENSAE, University of Dauphine, Paris and a Doctorat d'Etat in mathematical Economics from University Pierre et Marie Curie, Paris. He has widely published (more than 100 publications) and conducted research programmes in the areas of Energy Modelling, Macro-Economics, Operations Research and Mathematical Programming. He has built and used a variety of large-scale mathematical models. He has more than 15 years professional experience of consultancy in the domain of energy and economic policy.

Leonidas Mantzos holds an engineering degree and a Ph.D. degree in Energy Economics and Modelling from the National Technical University of Athens. He has been a senior researcher at ICCS-NTUA since 1998. He has 10 years experience in energy modelling, in particular in the construction and running of the MIDAS energy model for all European countries and the market equilibrium energy model PRIMES. He participated as main researcher in several energy analysis projects of the European Commission.

1 Introduction

The baseline scenario presented here is based on the assumption that EU policies currently in place will remain unchanged. This is clearly an important though unrealistic

assumption. However, since one of the objectives of the analysis is to assist policy makers in the evaluation of a number of alternative measures, it is appropriate that the baseline should form the benchmark against which the effectiveness of a number of alternative policies could be measured. In order to analyse policies aiming at curbing carbon dioxide emissions, any measures explicitly considered for climate change purposes are excluded from the baseline scenario. Still important drivers of change remain active in that baseline scenario. Energy market liberalisation, technology improvement in particular embedded in new capital enabling competitive energy production and use, local environmental problems and general expansion of customer coverage are among the main drivers of change that are included in the baseline scenario.

The process of baseline scenario building is difficult and important for policy analysis. The scenario presented here has been extensively based on the procedure established within the 'Shared Analysis' project of the European Commission that operated in 1998 and 1999 [1]. Within this activity, there has been extensive dialogue between the PRIMES modelling team and representatives or experts from the European Union member-states. The baseline scenario presented hereafter is different from the one finally retained in the 'Shared Analysis' activity. The main difference concerns the assumptions about the prices of energy as supplied to Europe. The scenario here generally assumes relatively higher energy prices than in the case of 'Shared Analysis'.

All scenario results are based on the PRIMES energy system model (version 2) as updated at the end of 1998 [2] and [3]. The text below puts emphasis on the technology developments as projected under baseline conditions. The paper does not provide full details on energy policy issues, for which the interested reader might refer to [1].

2 The key energy features of the baseline outlook

2.1 Key assumptions of the baseline scenario

Economic growth in the EU is expected to be just below 3% in the short run but it is assumed that, despite the generally favourable overall international context, the EU growth rate after 2000 will decelerate to levels that are consistent with long run historical trends. In the period 2000-10, the annual economic expansion is projected to be around 2.4% while, in the period after 2010, it is limited to less than 1.8%. The EU population is projected to increase by only 12 million people in the period to 2010 and to be effectively stable after that.

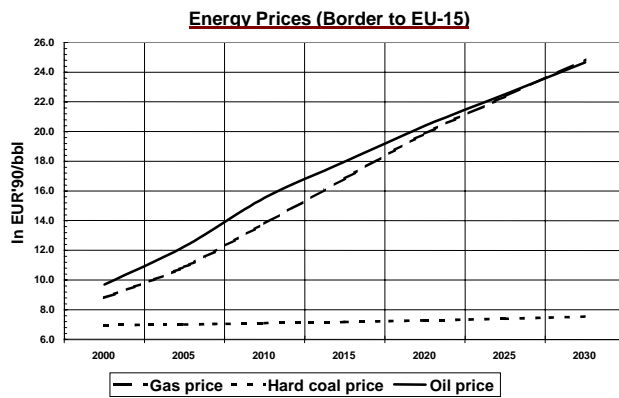
The long established trend of restructuring of EU economies away from the primary and secondary sectors and towards services and high value-added products (less material and energy-intensive products) is assumed to continue, although the pace of change is expected to decelerate in the long run.

The baseline scenario is based on the assumption that EU policies currently in place will remain unchanged. These include the further development of the liberalised electricity and gas markets in the EU, the further improvement of energy technologies in both the demand and supply sides, the continuation of support for renewables and co-generation, the preservation of current levels of energy fuel taxation in real terms, the extension of natural gas supply infrastructure and stringent regulation of acid rain

pollutants. The baseline scenario does not include any policies that specifically address the climate change issue.

Crude oil prices (at the EU border) by 2020 are projected to be close to 20 Eur'90/bbl, which is somewhat higher than their level of 1990 (in real terms) but above their level in recent years, and reach 25 Eur'90/bbl in 2030. Gas prices in Europe are assumed to rise significantly faster, by around 100% from their current levels in 2020, reaching, 25 Eur'90/bbl in 2030. The price of hard coal imported in the EU is expected to remain relatively stable (see Figure 1).

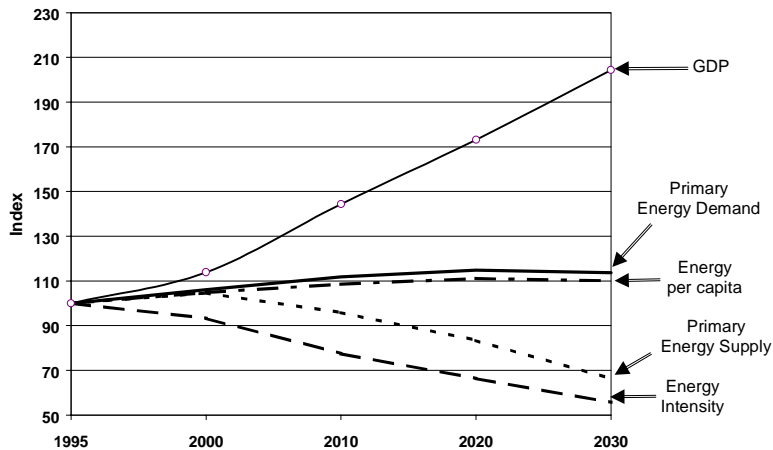
Figure 1 Primary fuel price assumptions



2.2 EU Primary energy supply and demand

The production of fossil primary energy within the EU is expected to continue to decline throughout the period to 2030, after peaking in the period 2000-2005. The decline of EU indigenous solids and oil is especially noticeable. Production of renewable sources of energy is likely to receive a significant boost as a result of policy and technology progress.

Despite the evidence of saturation for some energy uses in the EU, energy demand is expected to continue to grow in the short to medium term of the outlook period even though at rates significantly smaller than in history. The growth rate in primary energy consumption is expected to continue to be close to 0.7% over the period to 2010 and then to decelerate to just 0.3 % pa in 2010-2020 and stabilise in 2020-2030. Figure 2 shows the relative change of some key indicators of the energy system compared to their 1995 level (arbitrarily set at 100).

Figure 2 EU primary energy indicators, 1995-2030

Source: PRIMES

The implied energy intensity improvement is gradually expected to improve and to reach an annual rate of more than 1.7 % pa towards the end of the projection period (see Table 1). Structural change in the demand side mainly explains this change although the role of energy technology is also important.

The EU energy system remains dominated by fossil fuels over the next 35 years and their share rises marginally in the short to medium time horizon from its level of just under 80% in 1995. In the longer run the share of fossil fuels increases more significantly, reaching 85% of primary energy needs in 2030. This is a result of the large scale decommissioning of nuclear plants, which occurs in 2020-30 in the European Union.

Import dependency will gradually increase for all fossil fuels and is projected to reach very high values in the longer run. In 2030 more than 70% of overall energy requirements in the EU will be imported, compared to less than 50% in 1995.

Table 1 Primary energy demand, EU15

	Mtoe					% Annual growth rates				Shares, %			
	1995	2000	2010	2020	2030	95/10	10/20	20/30	95/30	1995	2010	2020	2030
Total	1363	1447	1524	1565	1550	0.7	0.3	-0.1	0.4				
Solid Fuels	237	204	191	222	300	-1.4	1.5	3.1	0.7	17.4	12.5	14.2	19.3
Liquid Fuels	574	608	633	631	602	0.7	0.0	-0.5	0.1	42.1	41.5	40.3	38.9
Natural Gas	273	332	394	402	412	2.5	0.2	0.3	1.2	20.1	25.9	25.7	26.6
Nuclear	205	223	216	196	117	0.3	-1.0	-5.0	-1.6	15.1	14.2	12.5	7.6
Electricity	1	2	2	2	2	4.2	1.7	0.6	2.5	0.1	0.1	0.1	0.2
Renewable En.	72	78	88	112	116	1.4	2.4	0.4	1.4	5.3	5.8	7.1	7.5
Sources													
Energy intensity (toe/MEUR90)	240	224	186	159	134	-1.7	-1.5	-1.7	-1.7				
Energy per capita (toe/cap)	4	4	4	4	4	0.5	0.2	-0.1	0.3				
Import dependency (%)	47.5	49.2	56.4	63.8	72.2	1.1	1.2	1.2	1.2				

Source: PRIMES

The use of solid fuels is expected to continue falling until 2010 both in absolute terms and as a proportion of total energy demand. Beyond 2010, however, due to the power generation problems that will ensue from the decommissioning of nuclear plants, and the loss of competitiveness of gas based generation, due to higher natural gas import prices, the demand for solid fuels is projected to increase. This increase is modest until 2020 and more rapid in the 2020-30 period.

Spurred by its very rapid penetration in new power generation plant and co-generation, gas is by far the fastest growing primary fuel in the short run. Its share in primary energy consumption is projected to increase further to 26% by 2010. The projection shows, however, only a modest increase beyond 2010. The consumption of gas accounts for 27% of primary energy needs in 2030.

The share of oil in primary consumption is projected to exhibit a small decrease over the period to 2030 and its annual growth rate is projected to decelerate from 0.7% in the period to 2010 to 0% during 2010-20 and -0.5% in 2020-30.

Under baseline technology assumptions, novel energy forms, such as hydrogen and methanol, do not make significant inroads, primarily due to cost considerations.

2.3 Final energy demand in the EU

Final energy demand is expected to grow marginally faster than primary energy (because of improved rates of conversion efficiency in power generation), rising by 1.4%, 0.4% and 0% in the 1995-2010, 2010-20 and 2020-30 periods respectively. As can be seen from Table 2 there are relatively modest changes in fuel shares in the horizon to 2030. The only notable change is the increase by nearly 7.5 points in the share of electricity, an increase that occurs to the detriment of solid and liquid fuels. However, even by 2030, electricity continues to account for a little more than a quarter of final energy consumption. The penetration of more efficient electrical technologies (such as heat pumps, advanced lighting and improved electric appliances) is noticeable.

Table 2 Final energy demand by sector and by fuel, EU15

	Mtoe					% Annual growth rates				Shares, %			
	1995	2000	2010	2020	2030	95/10	10/20	20/30	95/30	1995	2010	2020	2030
Total	885	954	1037	1080	1085	1.1	0.4	0.0	0.6				
<i>by sector</i>													
Industry	246	259	281	287	279	0.9	0.2	-0.3	0.4	27.8	27.2	27.1	26.5
Residential	240	255	263	274	287	0.6	0.4	0.4	0.5	27.1	26.8	25.4	25.4
Tertiary	124	141	152	165	187	1.4	0.8	1.2	1.2	14.0	14.8	14.7	15.3
Transport	275	299	341	354	333	1.5	0.4	-0.6	0.6	31.0	31.3	32.9	32.8
<i>by fuel</i>													
Solid Fuels	43	36	28	22	13	-2.7	-2.5	-5.2	-3.4	4.9	2.7	2.1	1.2
Liquid Fuels	403	434	467	470	449	1.0	0.1	-0.5	0.3	45.5	45.0	43.5	41.4
Natural Gas	177	197	207	202	206	1.0	-0.2	0.2	0.4	20.0	20.0	18.7	19.0
Steam	70	76	90	102	105	1.7	1.2	0.3	1.2	7.9	8.7	9.4	9.6
Electricity	169	190	222	262	290	1.8	1.7	1.0	1.5	19.1	21.4	24.2	26.7
Hydrogen	0	0	0	0	0	-	19.6	1.5	-	0.0	0.0	0.0	0.0
Methanol-Ethanol	0	0	0	0	1	-	9.3	1.0	-	0.0	0.0	0.0	0.0
Ren. En. Sources	22	22	23	22	22	0.0	-0.3	-0.1	-0.1	2.5	2.2	2.0	2.0
<i>Biomass</i>	22	21	22	21	20	-0.1	-0.5	-0.3	-0.3	97.4	96.1	94.3	92.2
<i>Other</i>	1	0	1	1	2	2.7	3.7	3.1	3.1	2.6	3.9	5.7	7.8

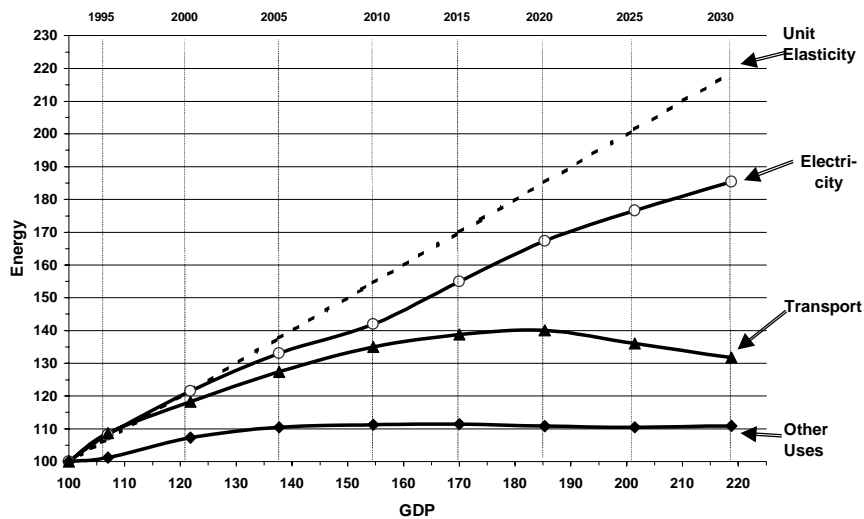
Source: PRIMES

Energy demand in the tertiary sector is the fastest growing segment of final demand reflecting the expected restructuring of the economy towards services. The modest growth in residential energy demand reflects the lack of growth in EU population and the small increase in the number of households. By 2030, transportation accounts for almost a third of EU final energy consumption, followed by industry and the residential sector, which account for around 26% of consumption each.

Oil becomes almost exclusively a fuel for transportation and petrochemicals. The increase in transportation energy demand is actually greater than the increase in the demand for liquid fuels over the 1995-2030 period, implying a decline in oil consumption in the other sectors.

Figure 3 illustrates the different trends observed in the evolution of final energy demand when associated to the evolution of gross domestic product.

Figure 3 Energy as a function of GDP (Index 100 in 1990), 1990-2030



Source: PRIMES

2.4 Power generation in the EU

The use of electricity is expected to expand by 1.5 % pa over the projection period and its growth is expected to be especially rapid in the tertiary and in the transportation sector. Steam demand is projected to grow by 1.7 % pa in the period to 2010, 1.2% pa in 2010-20 and by 0.3% in the 2020-2030. The industrial sector is projected to remain the dominant user of steam.

Table 3 demonstrates that the total power capacity requirements for the EU increase by some 385 GW in the 1995-2030 period and an amount of more than 575 GW of new capacity will be required for the replacement of decommissioned plants. Thus, the EU is projected to build 963 GW of new plants over the 1995-2030 period in order to cover its growing needs and replace the decommissioned plants.

Table 3 Power generation capacity by type of plant, GW, EU

	GW				% Annual growth rates				Shares %			
	1995	2010	2020	2030	95/10	10/20	20/30	95/30	1995	2010	2020	2030
Nuclear	132	135	115	61	0.2	-1.6	-6.2	-2.2	23.1	18.9	13.2	6.4
Coal and Lignite	180	101	37	9	-3.8	-9.6	-13.1	-8.2	31.5	14.1	4.2	1.0
Open Cycle multi-Fired	66	47	20	6	-2.2	-8.1	-12.1	-6.8	11.5	6.5	2.3	0.6
Open Cycle of IPP	33	25	27	26	-1.9	0.9	-0.1	-0.6	5.7	3.4	3.1	2.8
GTCC and small GT	46	246	304	328	11.8	2.2	0.8	5.8	8.1	34.3	34.7	34.3
Clean Coal and Lignite	0	2	2	6	9.1	0.0	14.4	7.9	0.1	0.2	0.2	0.7
Supercritical coal	0	0	158	261	-	-	5.2	-	0.0	0.0	18.0	27.3
Biomass-Waste of Utilities	4	14	24	32	8.7	5.7	2.9	6.1	0.7	1.9	2.7	3.3
Fuel Cells	0	0	0	43	-	-	-	-	0.0	0.0	0.0	4.5
Hydro-Renewables	109	147	191	183	2.0	2.7	-0.4	1.5	19.2	20.5	21.8	19.2
Total Capacities	570	716	878	956	1.5	2.1	0.9	1.5				

Source: PRIMES

The use of traditional coal and oil plants declines very rapidly. The capacity of conventional thermal plants currently utilised by independent producers decreases by one third until 2010 and remains rather stable at that level in 2010-30. Due to the decommissioning of older plants, there is a modest decline in the capacity of nuclear plants until 2020. However, in 2020-30 the large scale decommissioning of nuclear plants results in a decrease of nuclear capacity to less than half of that installed in 1995.

These declines in capacity are more than made up from the dramatic increase in the capacity of new plant types:

- The capacity of gas turbine combine cycle plants and small gas turbines increases more than 6 times until 2020, exhibiting a moderate increase thereafter. Their capacity reaches 330 GW, or almost 35% of total installed capacity in 2030;
- The role of supercritical coal plants becomes significant in the 2010-30 period. Almost 160 GW of supercritical coal plants are installed in 2010-20 and another 100 GW in 2020-30. In other words, supercritical coal plants take the place of decommissioned nuclear plants in the European power generation system and account for more than 27% of total installed capacity in 2030;
- The generation by other clean coal plant types and biomass is also expected to increase over the next 30 years, in particular towards the end of the projection period. However, these forms of power generation will still only account for less than 5% of total generation capacity by 2030;
- Fuel cells emerge in the power generation system only in the 2020-30 period. However their penetration is rapid and their capacity, more than 40 GW in 2030, accounts for 4.5% of total installed capacity.

Growth in hydroelectricity and other renewable forms of generation is projected to be modest but at more than 80 GW of new capacity until 2020, the increase in these capacities will make a significant contribution. The additions mostly concern wind power. The rather limited technical lifetime of wind turbines, combined with the emergence of new fossil fuel plant technologies results in a small decrease of renewable energy forms' capacity in 2020-30.

Table 4 Fuel input in thermal plants for electricity and steam generation, Mtoe, EU

	Mtoe				% Annual growth rates				Shares %			
	1995	2010	2020	2030	95/10	10/20	20/30	95/30	1995	2010	2020	2030
Coal	121	94	135	228	-1.6	3.7	5.3	1.8	33.1	22.9	29.5	41.3
Lignite	50	49	49	49	-0.2	-0.1	0.0	-0.1	13.8	11.9	10.6	8.8
Oil	66	42	31	22	-3.0	-2.9	-3.3	-3.1	18.1	10.2	6.8	4.0
Natural Gas	77	160	169	171	5.0	0.6	0.1	2.3	21.1	38.9	36.8	31.1
Other Gas	28	34	36	38	1.3	0.6	0.4	0.8	7.8	8.3	7.9	6.8
Biomass-Waste	22	32	39	44	2.5	1.9	1.3	2.0	6.1	7.8	8.4	8.0
New Fuels	0	0	0	0					0.0	0.0	0.0	0.0
TOTAL Fuel	364	412	460	552	0.8	1.1	1.8	1.2				

Source: PRIMES

The changes in the structure of generation capacity result in significant changes of the input fuel mix for power and steam generation. As shown in Table 4, the use of coal and lignite declines quite dramatically between 1995 and 2010 but after that it recovers to reach, and marginally exceed (in 2020), its 1990 level. In the last decade of the projection, coal and lignite become the dominant fossil energy forms in power and steam generation, accounting for almost 50% of total fossil fuel input. This is due to the increased decommissioning after 2010-15 of nuclear plants, the high penetration of supercritical coal plants and the progressive increase in the price of natural gas relative to that of coal. The growth rate in natural gas consumption in power and steam generation is close to 5% over the period to 2010 and then decelerates to just 0.6 % pa in 2010-2020 and stabilises in 2020-2030.

2.5 Environmental issues

The rising share of fossil fuels leads to an increase in the carbon intensity of the EU energy system. Together with the modest increase in energy demand, this will lead to an increase in CO₂ and other energy related emissions. CO₂ emissions are projected to increase annually by 0.5% pa in the 1995-2030 period (see Table 5).

Table 5 CO₂ emissions by sector

	Mtn CO ₂				% Annual growth rates				Shares %			
	1995	2010	2020	2030	95/10	10/20	20/30	95/30	1995	2010	2020	2030
Total	3029	3245	3359	3597	0.5	0.3	0.7	0.5				
industry	379	376	348	301	0.0	-0.8	-1.5	-0.7	12.5	11.6	10.4	8.4
tertiary	203	212	179	188	0.3	-1.7	0.5	-0.2	6.7	6.5	5.3	5.2
households	427	429	423	423	0.0	-0.1	0.0	0.0	14.1	13.2	12.6	11.8
transport	800	984	1020	963	1.4	0.4	-0.6	0.5	26.4	30.3	30.4	26.8
electricity-steam production	1162	1201	1354	1695	0.2	1.2	2.3	1.1	38.4	37.0	40.3	47.1
biofuels production	0	0	0	0	-	-	-	-	0.0	0.0	0.0	0.0
hydrogen production	0	0	1	1	-	19.6	1.5	-	0.0	0.0	0.0	0.0
energy branch	59	43	34	26	-2.0	-2.4	-2.7	-2.3	1.9	1.3	1.0	0.7
CO₂ emission index (1990=100)												
Total	98.7	105.8	109.5	117.2								
industry	89.2	88.7	82.1	70.9								
tertiary	105.2	109.8	92.7	97.3								
households	95.3	95.8	94.5	94.6								
transport	108.8	134.0	138.7	131.0								
electricity-steam production	95.9	99.1	111.7	139.9								
biofuels production	-	-	-	-								
hydrogen production	-	-	-	-								
energy branch	103.6	76.4	60.1	45.5								

Source: PRIMES

In the period to 2010, the sectors with the fastest increase in emissions are those where energy demand is expected to grow fastest, namely the tertiary and transportation sectors. However, in terms of their absolute contribution to the increase in emissions, it is the transportation sector, which accounts for nearly two thirds of the overall increase in emissions between 1995 and 2010. Beyond 2010, the electricity and steam generation system is almost solely responsible for the increase in CO₂ emissions.

Emissions of SO₂ and NO_x from the energy system as a whole and from the power generation system are expected to decline quite rapidly over the outlook period. By 2030 NO_x emissions from power and steam generation (large combustion plants) will be at nearly half their level of 1995 while SO₂ emissions almost diminish and are close to zero for 2030.

3 Technological development in baseline; benefits and implications

3.1 Introduction

The PRIMES model includes 10 industrial sectors (and a large number of industrial processes and energy uses), 4 tertiary sectors, 4 types of households, 4 transport means (separate passenger and goods transport) and the supply side.

Technological assumptions play a very important role in the derivation of the energy demand trends. It is important to note that the role of technology becomes more important as we move further into the future. This is mostly because of the longevity of the energy using capital stock.

In supplying each energy use, technologies compete against each other. Their technical-economic characteristics, such as costs and energy performance, evolve over time. The technologies are categorised in stylised clusters that include three generations in terms of their advanced energy features:

- Ordinary technologies, this category includes conventional technologies and new techniques that are mature in the market;
- Improved technologies, technologies that emerge in the market and are considered when investment decisions are to be taken;
- Advanced technologies, including technologies of high performance that may be commercially immature or experimental.

The progress of these technology generations over time drives the dynamics of technology improvement. In sectors or scenarios that involve accelerated capital turnover or a high level of investment in new equipment there is a tendency for a higher proportion of high technology to be embedded in the operating capital stock. In these cases, the suppliers of advanced technologies (equipment manufacturers, maintenance and technical support operators) anticipate higher demand for the advanced technologies and, through production on a greater scale, make them more attractive and more acceptable by the market. This technology supply-side effect [4] contributes to the acceleration of adoption of new technologies by consumers. Of course, both the availability of technologies and the technology adoption mechanism take into account the time limitations regarding

system adjustment. In other words the dynamics of technology change become more important in the long run.

Energy savings are defined at the level of energy use and correspond to direct measures, such as insulation, heat recovery, control systems, etc. Energy savings follow a highly non-linear cost supply curve and their potential is higher when ordinary technologies prevail in the operating capital stock.

3.2 *Technological development in baseline scenario for the demand side*

As already mentioned the baseline scenario for the EU assumes continuation of current trends and policies, including technology progress in both demand and supply.

Efficiency gains differ between the different demand sectors reflecting sectoral energy and capital intensiveness, the dynamic trends of technology progress that improves the efficiency of the energy system and the effects of the observed sectoral pattern of economic growth that shifts away from traditional energy intensive sectors and operates through high value added activities.

Table 6 summarises the improvement of energy intensity indicators at the level of the model's sectors. It can be seen that energy intensity improvements are especially rapid in the latter part of the projection period.

Table 6 Energy intensity improvement in the demand side

indicator (1995=100)	1995	2010	2020	2030
Industry (production related)				
iron and steel	100.0	88.5	78.6	59.5
non ferrous metals	100.0	83.0	76.0	64.5
chemicals	100.0	82.2	75.7	66.8
building materials	100.0	98.0	90.6	83.6
paper and pulp	100.0	94.1	85.7	76.4
food drink tobacco	100.0	97.6	91.7	86.7
engineering	100.0	96.9	88.8	81.8
textiles	100.0	97.5	91.5	86.3
other	100.0	97.1	90.5	84.6
Tertiary (value added related)	100.0	82.3	73.6	69.5
Households (income related)	100.0	78.4	68.3	60.5
Transport				
passenger (income related)	100.0	89.0	77.9	59.5
goods (GDP related)	100.0	84.6	72.0	62.9

Source: PRIMES

3.3 *Industrial sectors*

Energy intensive industrial sectors, such as the metal industries, chemicals, and the paper and pulp industries, achieve up to more than 40% intensity gains, between 1995 and 2030 while the energy intensity improvements in capital and labour intensive sectors is limited to around 3% in 2010 and 15% in 2030, when compared to 1995.

Restructuring of industrial processes (e.g. the increase of electric arc processing instead of integrated steelworks in the iron and steel sector, the increase of recycled

material processing in aluminium, glass and paper production) play an important role in improving energy intensity (see Table 7). Energy intensity also improves because of the shift towards higher value added production (e.g. the increased contribution of low energy chemicals to sectoral value added).

Table 7 Structural and technological changes in industrial sectors

	1995	2010	2020	2030
Process Technology Improvement (index, 1995=100)				
Iron and Steel	100	100	101	101
Basic aluminium	100	100	103	103
Processing of other non ferrous metals	100	104	110	125
Chemicals	100	108	114	124
Cement Production	100	102	109	118
Glass basic processing	100	103	112	114
Pulp and Paper	100	107	118	133
Structural Change in basic processing (% of production)				
Electric steelworks	32	47	56	78
Aluminium recycling	58	79	83	92
Glass recycling	49	59	65	80
Paper recycling	66	72	75	82
Changes in the fuel mix				
<i>electrotechnologies</i>				
% of mechanical processing in chemistry	61	63	71	71
% of electric furnaces non ferrous	70	82	84	90
% of mechanical processing glass production	15	17	19	22
% of mechanical processing in paper and pulp	66	68	65	64
% of heat pumps in specific heat uses	0	3	20	46
<i>natural gas directly substituting other fossil fuels (% in specific uses)</i>	41	49	51	56
<i>market share of steam (% in industrial demand)</i>	22	24	25	27
Contribution of CHP for industrial Steam Production (%)	51	67	72	90
Equipment efficiency of electrical and cross-cutting technologies (index, 1995=100)				
<i>Industrial Furnaces</i>				
Process Furnaces	100	102	106	110
Electric Furnaces	100	103	109	121
<i>Industrial Motors, Air Compressors, Lighting, etc.</i>				
Motor Drives	100	101	105	109
Air Compressors	100	103	109	114
Lighting	100	104	109	115

Source: PRIMES

The bulk of energy intensity improvement in iron and steel occurs due to the significant structural shift in favour of electric arc processing, the share of which more than doubles in 1995-2030. The energy requirements of electric arc processing are close to one third of those of integrated steelworks. No significant improvement is observed in the baseline for process specific technologies in integrated steelworks.

The findings and in the case of non-ferrous metals, production, are similar. A significant shift is observed in favour of recycled aluminium processing, which accounts for more than 90% of total aluminium production in 2030 (compared to 60% and 80% in

1995 and 2020 respectively) and has energy requirements that are less than 15% of those of basic aluminium processing. However, beyond 2010, significant technological improvements are observed for other non-ferrous metals (including secondary aluminium production) specific process technologies, reaching 25% in 2030 when compared to the level of efficiency of 1995. This improvement is achieved through the adoption of improved technologies in furnaces, kilns and electrolysis plants. For example, the share of electric furnaces in non-ferrous metals industries increases from 70% in 1995 to 90% in 2030.

The efficiency improvement in specific process technologies of chemical industries, mainly electrolysis, improves moderately in the baseline scenario reaching 25% in 2030 (8% in 2010) in comparison to 1995. In addition, there is a significant shift of the European chemical industries towards low energy /high value added products that are not energy intensive. The above factors and the increased use of heat pumps in specific heat uses in chemicals result in an improvement of sectoral energy intensity by more than 30% in 2030, when compared to 1995.

Energy intensity in building materials remains rather stable until 2010 (2% improvement from 1995). The increased level of recycled glass processing, which rises from 50% in 1995 to 80% in 2030, and the technological improvement in both glass and cement production processes, by 18% and 14% respectively, lead to an additional improvement in the efficiency of the sector by almost 15% in 2010-30. Technological improvement in cement production is achieved through the partial adoption of advanced cement kilns, involving improved furnace design and waste/heat recovery. In addition, advanced electrical-technologies for mixing, grinding and milling, also lead to efficiency gains. The results also show a significant shift towards electric glass furnaces, instead of fossil fuel fired ones (from 15% in 2010 to 22% in 2030). This improves the overall specific energy consumption of glass production.

The technological progress in paper and pulp basic processing is significant, amounting to 7% in 2010 and to more than 30% in 2030, when compared to 1995. The main changes regard heat and electricity savings enabled by heat management techniques and electrical-technologies respectively. The role of the latter is important, allowing for significant savings in mechanical treatment and refining. The share of processing of recycled paper increases from 66% in 1996 to 72% and 82% in 2010 and 2030 respectively, providing additional energy intensity improvement.

The other industrial sectors produce equipment goods (e.g. vehicles, household appliances, machinery, etc.), food, beverages and tobacco, textiles and other goods (e.g. wood products, rubber, construction, etc.). These sectors generally are not energy-intensive. The energy uses in specific product processing are very limited, mainly including coating and foundries in the equipment goods industry and some other sectors. The use of steam is significant in food processing, while low enthalpy heat uses (e.g. for drying and separation) are present in many sectors. Most of the technologies are crosscutting, including motor drives, compressors, heating and cooling, etc. Energy intensity ratios are computed against value added measured in monetary terms (and not against an indicator of physical production as in the other industrial sectors, mentioned above). The baseline scenario projects rather moderate improvements of energy intensity in these sectors over the outlook period. The improvement in 2010, when compared to 1995, ranges from 2.5% to 3%, while in 2030 it reaches up to 20%. This intensity improvement can be attributed to the technological evolution of cross-cutting

technologies, fuel substitution in favour of natural gas, electricity and steam, as well as the increased use of heat pumps in specific heat processes.

3.4 Households and tertiary

Energy is used in households and in the tertiary sector to provide a variety of services such as lighting, space heating, air conditioning, water heating, cooking and use of electric appliances.

The baseline scenario projects increasing energy use per capita in houses (7% increase in the period 1995 to 2010 and 9% in the period 2010 to 2030). The energy intensity, expressed as the ratio of final energy demand to household income, declines by an average of 1.4% per year during the projection period (see Table 5). The main reason for this decline is that many energy uses in households are close to saturation. Consequently, as incomes rise, households tend to consume more less energy intensive goods and services. Technology progress as projected in the baseline also contributes to the improvement of energy intensity in households.

Table 8 Structural and technological changes in households and tertiary

	1995	2010	2020	2030
Energy per capita in households index (1995=100)	100	107	111	116
Share of electric appliances to final energy demand (%)				
Households	9	10	11	13
Tertiary	12	13	17	20
Efficiency in space heating equipment (index, 1995=100)				
Households	100	104	115	126
Tertiary	100	108	131	141
Electric Equipment in Households (index, 1995=100)				
Refrigerators	100	128	164	171
Washing machines	100	136	163	167
Lighting	100	101	102	104
TV and similar	100	105	110	111
Water heating	100	120	138	143
Air Conditioning	100	106	132	172
Electric Equipment in Tertiary (index, 1995=100)				
Services	100	135	147	148
Agriculture	100	105	109	112

Source: PRIMES

The baseline scenario projects significant efficiency gains in space heating. This is due to the adoption of more efficient technologies and to the shift in favour of electric equipment (mostly heat pumps), whose market share increases by 7.5% in 2030 (3.5% in 2010) from its level of 1995. The overall gains in terms of equipment efficiency in space heating reaches 4% by 2010 and 25% in 2030, as compared to 1995.

More efficient equipment also enables efficiency gains in water heating (20% in 2010 and more than 40% in 2030 from 1995 levels), cooking (4% and 10%) and air conditioning (6% and a very significant 72% in 2030 – the result of the high penetration of heat pumps in households).

The adoption of more efficient technologies for electric appliances of all kinds is an important mechanism in the baseline scenario. Specific energy consumption of refrigerators improves on average by 28% in 2010 and 71% in 2030 (compared to 1990). This rate is as high as 36% and 67% for washing machines, 16% and 34% for dryers, 5% and 11% for TV sets and other small electric appliances. The average efficiency of lighting improves very modestly in the baseline due to the assumption of increased comfort standards.

The projected improvements in the efficiency of electric appliances is due to the expected availability of low cost and more energy-efficient electric technologies, a result of market competition among manufacturers, and to European policy initiatives that impose high efficiency standards and the labelling of appliances. It is also facilitated by the limited life span of most appliances and their consequent replacement by more efficient ones.

Regarding the tertiary sector, the overall energy intensity of the sector decreases substantially, by 17.5% in 2010 and by more than 30% in 2030 when compared to 1995. The share of electricity in the tertiary sector rises from 35% in 1995 to 40% in 2010 and to more than 50% in 2030.

The baseline extrapolates technology progress varying by type of equipment. The average energy efficiency of equipment used in thermal energy uses improves slowly. The efficiency of space heating improves by 8% over the 1995-2010 period and by more than 40% in 2030, when compared to 1995. The average efficiency of electrical equipment used in tertiary is projected to improve by 35% and 48% in 2010 and 2030 respectively from its 1995 levels.

3.5 *The transport sector*

The transport sector was the largest energy consumer in 1995 at the European Union, representing about 31% of total final energy demand. The baseline scenario extrapolates past trends showing high growth of mobility and freight transport. However, because of technology progress and structural changes in transport modes, energy demand grows at lower rates.

Table 9 Structural and technological changes in transport

	1995	2010	2020	2030
Travel per person (km/capita)	12289	15137	17457	19663
index (1995=100)	100	123	142	160
Activity per unit of GDP (tkm/000 EURO90)	280	254	238	224
index (1995=100)	100	91	85	80
Vehicles efficiency indicator (index, 1995=100)				
passenger transport	100	102	113	141
goods transport	100	107	118	127
Road transports efficiency indicator (index, 1995=100)				
private cars	100	101	112	144
trucks	100	101	108	122

Source: PRIMES

The technology of vehicles improves very slightly in the baseline until 2010. It must be noted here that the voluntary agreement between the European Commissions and the

European Car Manufacturers (ACEA) is not incorporated in the baseline scenario. If such an agreement proves to become effective, the average energy performance of cars could substantially improve at low cost for the consumer (by 18% in 2010 according to PRIMES-based sensitivity analysis runs). Under baseline conditions not involving the EC-ACEA agreement, this improvement is delayed and occurs after almost a decade.

Efficiency improvement in goods transport over the 1995-2010 period reaches 7% mainly due to the shift towards the use of trains and inter-modal optimisations.

Beyond 2010, the accelerated replacement of vehicles, as well as the maturity gained through the gradual introduction of new improved vehicle technologies, lead to a significant improvement of vehicle efficiency, reaching 41% for passenger transport and 27% for goods transport, as compared to 1995.

3.6 Baseline technological developments for the supply side

The introduction of new types of power plants leads to a significant improvement in the efficiency of power generation (see Table 10). The efficiency of the overall power and steam generation system is expected to increase by around 10 percentage points by 2010, to reach a maximum of 68% by 2020 and to stabilise at this level until 2030. The efficiency of generation of electricity, i.e. excluding steam production, improves from 34% in 1995 to 42% in 2010 and to 48% in 2030. This is the combined effect of adopting more efficient technologies (like GTCC and/or supercritical coal plants) and co-generation.

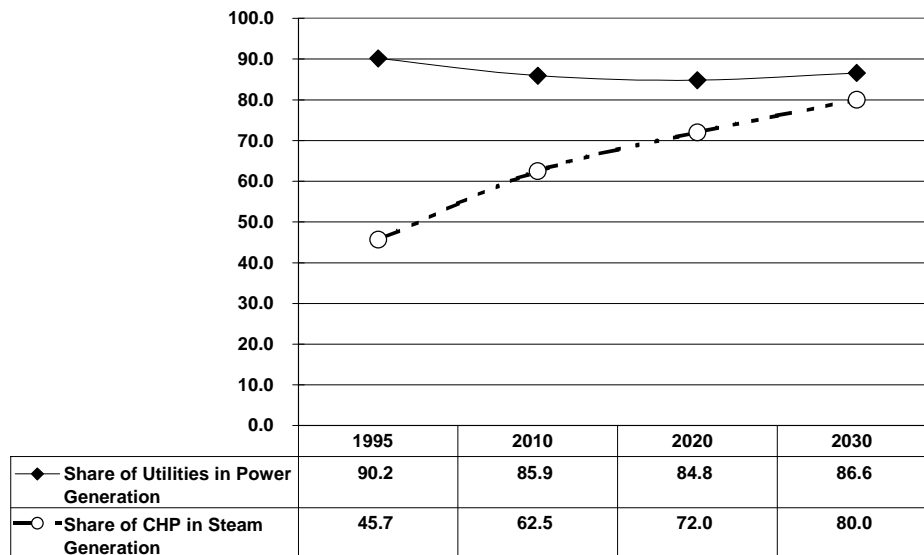
Table 10 Power generation efficiency, EU

	indicator				% Annual Change			
	1995	2010	2020	2030	95/10	10/20	20/30	95/30
-for total electricity & steam	0.54	0.64	0.68	0.67	1.2	0.5	0.0	0.7
-for electricity including CHP	0.42	0.56	0.60	0.62	2.0	0.8	0.2	1.1
-for electricity excluding steam	0.34	0.42	0.45	0.48	1.4	0.6	0.6	1.0
-normalised for electricity only	0.35	0.44	0.47	0.49	1.5	0.6	0.5	1.0
-normalised for steam only	1.28	1.69	2.11	2.72	1.9	2.2	2.6	2.2

Source: PRIMES

Technological advances and changes in market structure will reduce the dominance of utilities in electricity generation in the short to medium time horizon. This trend is clearly related to the widespread use of gas turbines since with this form of generation, economies of scale are very limited above a rather modest size of a turbine. In the long run, fuel cell is the key technology used in decentralised electricity and steam production. Small-scale producers are projected to take a share close to 14% of the electricity market by 2010 and remain roughly at that level beyond 2010 (see Figure 4).

The use of gas turbines and fuel cells in combined cycle mode will also greatly encourage the more widespread use of steam, especially by independent producers. The market share of co-generation plants continuously increases in power and steam generation as time evolves. While about 46% of steam was produced from such plants in 1995, the rest being produced from boilers, this share increases to 63% in 2010 and 80% in 2030.

Figure 4 Share of utilities in generation and the share of cogeneration

Source: PRIMES

4 Issues emerging from the EU outlook

The baseline outlook for the EU provides a detailed projection for the EU energy system to 2030. Although the gross domestic product of the EU is expected to more than double in 1995-2030, primary energy needs exhibit a significantly lower increase of about 20%. This is the result of an average energy intensity improvement of 1.7 pa in 1995-2030, which is due to structural changes in the economy, saturation of energy needs and autonomous technical progress.

The role of fossil fuels increases over time and they account for about 85% of primary energy needs in 2030, compared to 80% in 1995. The large scale decommissioning of nuclear plants combined with the rather moderate penetration of renewable energy forms in the EU energy system lead to this result. Oil remains the main energy source, followed by natural gas and solids. The latter exhibits a significant comeback in 2020-30 as coal plants are used to replace decommissioned nuclear capacity. The share of coal drops from 17.5% in 1995 to 12.5% in 2010 and then increases to 14.2% in 2020 and 19.3% in 2030. Under baseline assumptions the EU will not meet its Kyoto undertakings, at least through energy related CO₂ emissions. Instead of the 8% reduction in emissions by 2010 a 5.8% increase is projected. The increase in emissions reaches more than 17% in 2030, when compared to the level of CO₂ emissions in 1990. Depending on the outlook and policy measures for non CO₂ greenhouse gases, such as CH₄, it is clear that a number of policy initiatives will have to be undertaken for the abatement of energy related emissions.

The outlook for nuclear power is one of the key uncertainties regarding the EU energy system in the longer term. Nuclear energy can play a very significant role in reducing

emissions beyond 2010. Its impact will depend on whether the massive amount of nuclear plants that are due to be decommissioned between 2015 and 2030 will be replaced by nuclear plants or by fossil fuel plants.

Another uncertainty of the baseline outlook is that of the evolution of international fuel prices. Under the assumption of higher availability of resources and therefore lower prices for crude oil and natural gas, the observed expansion in the use of solids in the power and steam generation would not occur and CO₂ emissions in the long run would be substantially lower.

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