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Description of the Energy System of Spain

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46 pp. 9 fig. 39 Tablas 56 ref.

Abstract:

The objective of this report is to describe the complete Spain energy system, in order to make possible its modelling with the TIMES model within the NEEDS project (http://www.needs-project.org).

Descripción del Sistema Energético Español

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Resumen:

El objetivo de este trabajo es describir el sistema energético español para así hacer posible su modelización con el modelo TIMES dentro del proyecto NEEDS (http://www.needs-project.org).

Esta tarea se ha desarrollado en el marco del proyecto NEEDS dentro del 6º PM de la CE.

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1. General description of the country

Located in the South-Western part of Europe, with an area of 505,000 km^2, Spain comprises 85% of the Iberian Peninsula, the Balearic and Canary Islands as well as the cities of Ceuta and Melilla, in the northern part of Africa. By 2005, total population reached 40.3 million, mostly due to the large flow of immigrants. Population growth seems to be surpassing forecasts, which predicted 42.5 million inhabitants by 2010. The average population density is 80 inhabitants/km^2 although it is very variable across regions. 22% of the total population lives in 7 main cities of Spain (Ciemat, 2005).

Figure 1: Map of Spain

Spain joined the European Union (EU) in 1986 and since then, it has witnessed a rapid economic growth, averaging a five percent annual growth. The last figures show a 3,7% growth rate (INE, 2006). In 2004, total GDP amounted 798,000 million Euros which represents 13,500 Euros per capita. Within sectors, industry contributes to 31% of the total GDP and employs 28.6% of the working population. Services contribute to 65% of the GDP and also employ 65% of the population. Finally, agriculture contributes to 4% of the GDP and employs 5.7% of the working age population. The major economic challenges that Spain is currently facing are: adjusting to the monetary and other economic policies of an integrated Europe, absorbing widespread social changes –for example: large flows of migrants from Africa- and reducing unemployment. In terms of inflation, the consumer price index (CPI) growth rate in 2005 was 3.4%. Finally, public debt represents 48.5% of GDP.

Indicator	Units	1995	2000	2004
Population	Millions	39.3431	40.0497	42.3453
GDP in Purchasing Power Standards	% with respect to EU25	86.8	92.4	97.3
Annual GDP growth	annual % growth	5	4.2	3.1

Table 1: Main demographic and economic indicators. Source. Eurostat, 2006.

2. The national energy system and the modelling assumptions

2.1 Supply

Spain´s primary energy supply in years 1990, 2000 and 2004 is shown in table 2.1 below. Spain largely bases its primary energy supply on petroleum products (more than 50%) as well as coal products. Gas has greatly increased its share in the primary energy supply over the last few years, while nuclear energy remains constant in absolute figures but decreases its share in the primary energy supply. Renewable energies still provide a reduced amount of primary energy although wind energy is experiencing an important increase over the last years.

Energy carrier	**1990**	**%**	**2000**	**%**	**2004**	**%**
Coal	18717	20	20376	16	20628	14
Petroleum products	49960	53	70091	54	75779	52
Gas	4963	5	15615	12	24925	17
Nuclear	13701	15	16046	12	16407	11
Heat	-		-		-	
Renewables	6255	7	7029	5	8977	6
biomass (wood and wood waste)	3956		3623		4026	
biogas	10		131		253	
biofuels	-		65		248	
geothermal	2		8		8	
hydro	2184		2534		2713	
wind	1		406		1341	
solar PV	-		1		9	
solar heat	21		31		54	
MSW	81		229		326	
Industrial Wastes	-		-		-	
Net electric imports	-36	-0.04	386	0.3	-263.25	-0.18
Total	**93580**		**129696**		**146455**	

Table 2.1. Total primary energy supply by energy carrier (1000 toe). Source: Eurostat, 2006; REE, 2006; IDAE, 2000; IDAE, 2005

2.1.1. Fossil Fuels (oil, gas and coal)

2.1.1.1. Reserves and domestic extraction

Spain has very scarce fossil fuel reserves. According to the Oil and Gas Journal (EIA, 2005), proven reserves of oil have been quantified in 0.158 billion oil barrels (909 PJ) and natural gas reserves in 0.09 trillion cubit feet (92 PJ). According to national data (IGME, 2006), proven reserves of coal and lignite are as follows:

Coal and lignite reserves	**Coal**	**Lignite**
Likely and very likely reserves	18 e+03	7.3 e+03
Hypothetical reserves	62 e+03	9.5 e+03

Table 2.2 Coal and lignite proven reserves in Spain year 2000 expressed in PJ.

The level of extraction of domestic oil reported in Eurostat for the year 2000 amounted 9.42 PJ, which is quite consistent with the domestic statistical data (9.55 PJ). From the information provided by the Spanish Association of Petroleum Product Operators (AOP), the cost of extraction of this domestic oil is around 15 $/barrel (2.61 Euro/GJ). The level of extraction of domestic natural gas was 6.2 PJ which is quite consistent with the domestic statistical data (6.45 PJ). The extraction cost of this domestic natural gas was obtained from the OECD report (OECD, 1998). Following the information from this report, it was considered the cost of natural at the well as 4.69 Euro/GJ.

The level of extraction of domestic coal and lignite was 331 and 75 PJ respectively. These values are higher that the values reported by Eurostat and therefore the Eurostat values were corrected accordingly. The extraction cost figure was also obtained from the OECD report and was considered to be 2.29 Euro/GJ as the cost at the mine. Uranium mining in Spain still had some production during the year 2000 and until the year 2002 when the last mine was closed (Foro Nuclear, 2006).

2.1.1.2. Imports

Due to the lack of significant domestic oil production, Spain must import large quantities of crude oil. The largest oil supply countries and prices for these imports are reported in table 2.3.

Countries	PJ	Euro/GJ
Niger	383.12	5.73
Mexico	307.53	4.12
Libya	289.38	5.55
Saudi Arabia	288.15	5.08
Iraq	260.28	4.99
Russia	217.39	5.06
Iran	165.09	4.80
Guinea	128.52	5.42
UK	79.89	5.65
Algeria	59.34	5.91
Venezuela	57.77	4.78
Tunisia	34.66	5.23
Angola	32.24	4.99
Syria	27.37	5.54
Gabon	11.48	4.81
Cameroon	11.34	4.71
Ukraine	6.22	5.06
Turkey	5.69	5.59
Congo	5.66	4.57
Italy	4.38	3.17
Kazajistan	3.75	5.31
Egypt	3.49	3.82
Brazil	1.24	4.41
United Arab Emirates	0.21	4.92
Total	2384	

Table 2.3. Crude oil imports. Quantities and prices in year 2000.
Source: AEAT, 2005.

Total value of crude oil imports according to National statistics is close to the Eurostat value of 2389 PJ.

With regards to natural gas, import figures are also quite important amounting 825 PJ according to the National statistics (AEAT, 2005). Of this amount, 379 PJ are liquefied natural gas and the rest are in gaseous form. The largest suppliers and the prices for these imports are shown in table 2.4.

Countries of origin	PJ	Euro/GJ
Liquefied natural gas	**376**	
Algeria	182	3.51
Nigeria	90	3.08
Trinidad y Tobago	41	3.36
Lybia	33	3.39
Qatar	12	3.07
United Arab Emirates	10	2.89
Oman	6	2.68
Malaysia	3	2.71
Gaseous natural gas	**446**	
Algeria	350	3.22
Norway	97	3.16
Total imports of natural gas	**822**	

Table 2.4. Natural gas imports. Quantities and prices in year 2000. (AEAT, 2005)

The Eurostat value for natural gas imports was 648 PJ, which is lower than the value found in the national statistics. The Eurostat value was thus replaced by the value found in the National statistics.

Spain imports natural gas through two international pipelines: the Trans-Pyrenean pipeline (330 million cubit feet per day) and the Maghreb-Europe gas pipeline (820 Mmcf/d but with a new compressor station the capacity will be increased up to 1.78 Bcf/d). An additional pipeline linking Algeria to Almeria is in project (Medgaz) with an initial capacity of 770 Mmcf/d.

There are several LNG receiving terminals in Spain with a total capacity of 6.8 Bcf/d.
Coal imports are quantified in 546 PJ in Eurostat, whereas only 439 PJ are found in national statistics. The Eurostat value has then been retained. The import price in Spain in year 2000 was 1.93 Euro/GJ (AEAT, 2005).

No lignite import is reported in neither Eurostat nor in National statistics. However, some more lignite is needed to fulfil the lignite consumption reported in Eurostat for other sectors. Therefore an additional amount of 9 PJ of lignite has been included in the balance sheet of the supply template.

Coke is also imported in Spain in an amount of 6.23 PJ according to the national statistics figures. 4 PJ of imported coke is reported in Eurostat, although 2 additional PJ are considered as stock change and therefore available in the system. Eurostat numbers have been retained in this case.

Feedstocks are also a commodity imported in the country. An additional amount of 81 PJ has been added to the amount imported, reflecting the value of imported refinery feedstocks in cell H24.

Petroleum imports and exports values reported in Eurostat are in close agreement with the values found in the Spanish official statistics records with the exception of the value for other petroleum products and petroleum coke imports. The value found in the domestic statistics amount 142 PJ instead of the 129 PJ reported by Eurostat. The value of Eurostat was thus replaced by the value found in national statistics. The import price of this commodity is around 2 Euro/GJ following the data found in the Spanish Foreign Trade office (AEAT, 2005).

2.1.1.3. Exports

Spain exports mainly hard coke as well as petroleum products. The values reported in Eurostat are in close agreement with the values found in national statistics and no additional adjustment has been made.

2.1.1.4. Modelling remarks

Imports/exports of coal and biomass commodities from European countries (eg. IMPCOAHARD from Europe) and those from Non-European countries (eg. IMPCOAHARA from South Africa) have been made distinct, so that the former can be converted in endogenous trade in the Pan-European model, and the latter kept as exogenous trade.

Oil products and gas trade were finally modeled in a different manner, using IMP*Y and EXP*Y, since the Pan-European model will use a specific module to compute them.

Current and future import prices have been adjusted in the Scen.Xbase.xls file. The growth of the projected prices is the same as the one proposed by Markus.

The overall level of imports is allowed to increase by a factor 5 until year 2005. Remind that oil and gas, whose import capacity depends on pipelines and therefore can not be “freely” increased, are not concerned by this increase since they are modeled in a separated manner.

Delivery costs of energy commodities have been calculated and added in Scen_Xbase.xls file. They apply to the final end-use technologies and not the fuel technology as suggested by Markus, since no clear agreement seems to have been reached as regards this decision. Therefore, it must be reminded that the sector fuels DO NOT reflect the delivery costs. Only the final demands do.

2.1.2. Electricity

Electricity installed power in Spain is largely based on fossil fuels – natural gas and coal- and hydroelectric power plants, as it is shown in table 2.5. However, in the last years a great increment of investments in wind electricity has taken place, with almost 10GW installed in year 2005, a 13% of total installed capacity in Spain. Over the last few years, there has also been a remarkable investment in natural gas combined cycle power plants, having reached an installed capacity of 12.2 GW which represents a 17% of total installed capacity in Spain.

Source	1990	%	2000	%	2004	%	2005	%
Nuclear	**6970**	16%	**7799**	15%	**7876**	11%	**7876**	11%
Conventional Thermal	**19038**	44%	**19756**	37%	**26745**	39%	**30295**	41%
Coal		0%	11542	22%	11565	17%	11424	15%
coal		0%	8009	15%	8032	12%	7891	11%
lignite		0%	3533	7%	3533	5%	3533	5%
Fuel/Gas		0%	8214	16%	6947	10%	6647	9%
CC Natural gas		0%		0%	8233	12%	12224	17%
Renewables	**16379**	38%	**20313**	38%	**27602**	40%	**29154**	39%
Hydro	16230	37%	17894	34%	18293	27%	18415	25%
Wind	7	0%	2079	4%	8442	12%	9800	13%
Other Renewables	142	0%	340	1%	867	1%	939	1%
CHP Autoproducers	**1178**	3%	**4968**	9%	**6496**	9%	**6645**	9%
TOTAL	**43565**	100%	**52836**	100%	**68719**	100%	**73970**	100%

Table. 2.5. Breakdown of installed electricity generation capacities between 1990 and 2005 (MW). Source: Eurostat,2006; REE, 2006.

In terms of electricity production, table 2.6 shows the shares of the different technologies. The largest share comes from fossil fuels, with an increasing participation of natural gas and a decreasing contribution of coal. Nuclear electricity remains constant over time in absolute figures but its contribution becomes less important in relative terms. Total contribution of renewables remains almost constant in relative terms with variable contribution of hydroelectricity depending on the hydrological year. However, wind electricity has remarkably increased in the last years representing in year 2005 a 13% of total electricity generated in the country.

Source	1990		2000		2004		2005	
Nuclear	**54270**	35%	**62206**	31%	**63606**	25%	**57539**	22%
Conventional Thermal	**68336**	45%	**86623**	43%	**113029**	45%	**136246**	52%
Coal	59734	39%	76374	38%	76358	30%	77393	29%
Fuel/Gas	8602	6%	10249	5%	7697	3%	10013	4%
CC Natural gas		0%		0%	28974	11%	48840	19%
Renewables	**27417**	18%	**37511**	18%	**53164**	21%	**47202**	18%
Hydro	26180	17%	31678	16%	34373	14%	22820	9%
Wind	14	0%	4462	2%	15753	6%	20377	8%
Other Renewables	1223	1%	1371	1%	3038	1%	4005	2%
CHP Autoproducers	**3038**	2%	**16962**	8%	**22481**	9%	**22332**	8%
Gross electricity generation	**153061**	100%	**203302**	100%	**252280**	100%	**263319**	100%
Consumption in operation	-8040		-12734		-13254		-15789	
International exchanges	-420		4441		-3027		-1343	
Net electricity generation	**144601**		**195009**		**235999**		**246187**	

Table. 2.6. Electricity production between 1990 and 2005 (GWh). Source: Eurostat, 2006; REE, 2006.

In 2005, Spain´s electricity net consumption reached 886 PJ, which represented a 4.3% increase over 2004 consumption. Over the last 10 years, demand has grown by 64.6%, with an average accumulated rate of 5.8%. Electricity consumption per inhabitant in 2004 was 19.8 GJ (5,500 kWh), with a growth of 38.6% during the last decade. Electricity intensity was 1,077 GJ/€.

Electricity consumption by sector is shown in table 2.7. The industry sector is the largest consumer of electricity in the country, followed by the commercial and residential sector.

Sector	1990	%	2000	%	2004	%
Industry	63279	50%	85640	45%	101525	44%
Commercial	25103	20%	50023	27%	60671	26%
Households	30210	24%	43619	23%	58046	25%
Transport	3669	3%	4163	2%	5235	2%
Agriculture	3538	3%	5014	3%	5192	2%
	125799		**188459**		**230669**	

Table 2.7 Electricity consumption by sector (Gwh). Source: Eurostat, 2006.

2.1.2.1. Electricity balance. Model assumptions.

Electricity generation in Spain has two different regimes, the ordinary regimen (R.O.) to which all the conventional generation belongs to and the special regimen (R.E) to which the renewable energy generation and the CHP plants belong to. In this last regime a feed-in tariff promotion mechanism is implemented. Electricity generated under the RO in year 2000 amounted 174 TWh, while the electricity generated under the special regime reached 27 TWh. The net output from international exchanges of electricity was 4.4 TWh, from which 8.7 TWh were imports from France and Portugal and 4.3 TWh were exports to France, Portugal and Morocco.

Eurostat values are slightly higher –amounting 215 TWh in total-, so they have not been corrected. This data aggregates public and autoproduction facilities. Therefore, to be able to model separately autoproduction and public generated electricity, the ELC template considers default shares for autoproduction/public generated electricity for each type of generation technology. These shares have been set according to national data from the Ministry of Industry, Tourism and Comerce (MITYC, 2005) and from the data available in Loesoenen (2003).

There is small public CHP capacity installed in Spain using municipal waste as fuel.

2.1.2.2 Technology characterization

National specific efficiencies, base-year utilization factors and cost data for each different technology type were introduced in the model. The data was obtained from the CNE (CNE, 2005) and from UNESA (UNESA, 2005). The utilization factors were slightly adjusted in order to fit the energy consumption statistics and electricity generation. Emission data for each power plant were available (CIEMAT, 2005) and were included in the model.

Parameter	Reference	Notes
Share Auto/public installed capacity	MYCIT, 2005 Loesoenen, 2003	
Installed capacity by fuel and type of technology	UNESA, 2005 CNE, 2005	
Efficiencies and utilization factors	UNESA, 2005 CNE, 2005	Utilization factors were adjusted in order to fit statistical final energy consumption
Emissions	CIEMAT, 2005	

Table 2.8. Key-parameters and references

The evolution of the 2000 stock for all electricity generators was set according to the start date of operation and the lifetime provided by UNESA. Lifetimes considered were the following:

- Thermal power plants (included biomass and waste) 40 years
- Nuclear power plants 40 years
- Hydro power plants 60 years
- Wind power plants 20 years

2.1.2.2 International trade of electricity

The international exchanges of electricity were obtained from national statistics (REE, 2001). These values differ considerably from Eurostat data, and were therefore introduced in the supply templates replacing Eurostat data. Electricity trade prices were set taking into account the information contained in (AEAT, 2005). Import price was considered to be 9.35 Euro/GJ and the export price 10.51 Euro/GJ.

Net international trade is considered to be constant over the horizon in the national models since any import should be reported in another country's model. Remind that electricity will be endogenously traded in the Pan-European model. The use of the national model in a standalone manner for specific policy analysis should therefore define different scenarios, given the crucial role of future electricity trade.

2.1.3. Renewables

In the reference year, 2000, there was a limited use of renewable energies in the energy system. However, over the past years such figure has been largely increased. Wind energy was the main renewable energy source in electricity production with 2.3 GW installed followed by biomass (0.2 GW) and biogas (0.1 GW). In year 2005 wind energy installed capacity reached 10 GW). Regarding biofuels, 2.7 PJ were used in the base year. In year 2005 this figure was 9.1 PJ.

2.1.3.1. Potentials

Renewable potentials were obtained from a Greenpeace's study (Greenpeace, 2006) and introduced in the main sheet of the supply template. Hydro potentials were considered to be higher that reported in the Greenpeace study in order to allow better hydrological years observed in the past (year 2001).The potentials considered are the following:

Source	Potential
Hydro Potential	135.36
Wind Potential	9428.4
Solar Potential	42653.88
Geothermal Potential	70.2
Biomass	285
Biogas	183

Table 2.9. Renewable potentials (PJ)

Regarding biofuels potentials the actual figures of biofuel production in year 2005 are reported in table 2.10:

Biofuels	Production (PJ)	Consumption (PJ)	Exports (PJ)
Biodiesel	2.7	1	1.6
Bioethanol	6.4	4.7	1.7

Table 2.10 Biodiesel and Bioethanol breakdown

Of the above exports of biodiesel, Germany imports most of it while bioethanol is mostly exported to Germany and Sweden.

Bioethanol is used trough conversion to ETBE, but in the future also splash blends up to a 5% (or 10% if finally allowed) will be used since the production capacity of isobutylene in Spain is already at its limit. Biodiesel is blended with diesel in several percentages. There is no need of different vehicles for these uses of biotehanol although the introduction of FFV vehicles using E85 is also possible. They are now available in the market but there is no distribution of E85 in the filling stations art the moment.

Following the information provided by the Spanish National Energy Commission, (CNE, 2005) there are 1 new bioethanol plant now in operation producing 6.8 PJ and 6 more in project that will produce 25.6 PJ. With regard to biodiesel there are 20 new more plants in project or in construction that will produce 58 PJ more.

Costs of producing biomass resources were obtained from the EU project VIEWLS (VIEWLS, 2005).

Biomass resources	Cost €/PJ
Wood Products	4.89
Municipal Waste Production	5.81
Industrial Waste-Sludge Production	5.81
Biogas Production	32.85
Biofuels Production	28.50

Table 2.11. Biomass production costs (PJ)

2.2 Demand

Spain's total final energy consumption in 2004 amounted 94.3 Mtoe. Over the last 10 years, total final energy consumption growth rate has been 40.4% with an annual growth rate of 9.2%. It is worth highlighting the remarkable increase in gas and electricity consumption, although the highest share corresponds to petroleum products representing more than 55% of total final energy consumption.

Final energy consumption by fuel in the country is shown in table 2.12.

Energy Carrier	1990	%	2000	%	2004	%
Coal	3524	6%	1671	2%	1870	2%
Petroleum products	33460	59%	45784	58%	52096	55%
Gas	4873	9%	11819	15%	16756	18%
Electricity	10817	19%	16205	20%	19834	21%
Heat	0	0%	74	0%	0	0%
Renewable	3933	7%	3466	4%	3763	4%
Solar energy	21	0%	31	0%	54	0%
Biomass (wood and wood wastes)	3900	7%	3337	4%	3424	4%
Biogas	10	0%	25	0%	29	0%
Geothermal	2	0%	8	0%	8	0%
Biofuels	0	0%	65	0%	248	0%
Industrial wastes	12	0%	81	0%	0	0%
Other	28	0%	322	0%	-2	0%
TOTAL	**56647**		**79422**		**94317**	

Table 2.12. Final energy consumption by fuel between 1990 and 2004 (ktoe). Source: Eurostat, 2006.

Regarding the distribution of final energy consumption by sector, the highest share correspond to the transport sector with more than 40% of total final energy consumption, followed by industry and residential sector.

Sector	1990	%	2000	%	2004	%
Industry	20014	35%	25474	32%	30660	33%
Commercial	3390	6%	6673	8%	7579	8%
Households	9266	16%	11871	15%	14365	15%
Transport	22326	39%	32858	41%	38398	41%
Agriculture	1651	3%	2526	3%	3277	3%
Other	0	0%	20	0%	39	0%
TOTAL	**56647**		**79422**		**94318**	

Table 2.13. Final energy consumption by sector between 1990 and 2004 (ktoe). Source: Eurostat, 2006.

2.2.1. Residential, commercial and agriculture

2.2.1.1 Residential:

In 2000 -according to the official national figures-, the residential total energy consumption amounted 497 PJ and the energy balance (in Ktep) is reported in table 2.14:

Residential Sector end uses	% of residential consumption	Ktep. Consumed in 2000
Heating systems	47.135%	5600.11
Water Heating systems	20.201%	2400.05

Lightening	7.482%	888.91
Domestic appliances	15.507%	1842.42
Cooking appliances	9.482%	1126.59
Cooling systems	0.193%	22.93
TOTAL	100%	11881

Table 2.14: Breakdown of residential energy consumption by end use category.

In terms of Eurostat Data, there were no major discrepancies with regards to national data, so no further changes were made to the original Eurostat values from the templates. In terms of the residential sector energy consumption breakout by end use and by building type, the following shares are shown in tables:

End-use description	RSDCOA	RSDLPG	RSDOIL	RSDGAS	RSDBIO	RSDSOL	RSDGEO	RSDELC	RSDLTH	RSDHTH
Space Heating	0.98	0.82	0.86	0.42	0.77	0.10	1.00	0.20	1.00	1.00
Space Cooling				0.08			0.00	0.06		
Water Heating	0.00	0.10	0.14	0.30	0.05	0.90	0.00	0.15	0.00	0.00
Lighting								0.12		
Cooking	0.02	0.08		0.20	0.18	0.00		0.18		
Refrigeration								0.18		
Cloth Washing								0.07		
Cloth Drying								0.01		
Dish Washing								0.02		
Other Electric								0.01		
Other Energy										
Total	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**

Table 2.15: Residential energy consumption breakdown by end-use

End-use	Building Type	RSDCOA	RSDLPG	RSDOIL	RSDGAS	RSDBIO	RSDSOL	RSDGEO	RSDELC	RSDLTH	RSDHTH
Space Heating	Single House-Rural	0.2	0.1	0.2	0.1	0.5	0.0	0.0	0.2		1.0
Space Heating	Single House-Urban	0.3	0.3	0.3	0.2	0.3	0.8	0.0	0.3		
Space Heating	Multi Apartment-All	0.5	0.6	0.5	0.7	0.2	0.2	0.0	0.5	1.0	
		1.0	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**0.0**	**1.0**	**1.0**	**1.0**
Space cooling	Single House-Rural				0.1				0.1		
Space cooling	Single House-Urban				0.3				0.2		
Space cooling	Multi Apartment-All				0.6				0.7		
					1.0				**1.0**		
Water Heating	Single House-Rural	0.0	0.2	0.2	0.1	0.6	0.2	0.0	0.2		
Water Heating	Single House-Urban	0.0	0.3	0.3	0.2	0.3	0.3	0.0	0.3		
Water Heating	Multi Apartment-All	0.0	0.5	0.5	0.7	0.1	0.5	0.0	0.5		
			1.0	**1.0**	**1.0**	**1.0**	**1.0**		**1.0**		

Table 2.16: Residential energy consumption breakdown by building type

To elaborate these values, since there was not a single report or data set that contained all the information, several <u>sources of information</u> were used which included, among others:

(i) - Consumo de Energía de los Hogares (INE-1995).
(ii) -Estrategia de Ahorro y eficiencia energética en España 2004-2012. Sector equipamiento residencial y ofimática – E4 (Ministerio de Economía, 2003)
(iii) – Proyecto INDEL. Atlas Demanda Eléctrica Española (REE, 1998).
(iv) - Informe sobre Consumo Doméstico de Energía (Ómnibus AC-Nielsen 2003).

None of the above mentioned reports included all the information required to complete the RSD-Balance (either because the publication date was prior to 2000 or because it did not provided enough detailed information). Consequently, it was necessary to combine the information coming from the different sources of data and to undertake some assumptions regarding the penetration share growth of the different residential technologies included in the "Consumo de Energía de los Hogares" (INE, 1995) or the " Proyecto Indel" (REE, 1998). The latter report provided us with trends and estimations for future technologies penetration.

To estimate the number of dwellings and the penetration rate of air conditioning systems, the following assumptions were made: The total number of dwellings (20529) was obtained from the 2001 National Census (INE, 2001). From the total number of dwellings in 2001, it has been subtracted those that were built in 2001 in order to estimate the number of dwellings existing in year 2000.

Rural and urban settings were distinguished utilising the population figures. In particular, it was considered urban any location with more than above 5.000 inhabitants, while the locations with less than 5.000 inhabitants were considered rural.

Indicator	Number	Modelling assumptions
Total number of households in 2000	20529	Based on 2001 census figures
Households multi-apartment	11763	Based on 2001 census figures
Household urban-single house	5030	Based on 2001 census figures (population larger than 5,000)
Household Rural-Single house	3736	Based on 2001 census figures (population smaller than 5,000)

Table 2. 17: Building categories- Residential

To estimate the share of dwellings with cooling system, the estimations presented in the Proyecto Indel (REE, 1995) report were used. The penetration index in 1997 (the year in which the report was written) was 8,2% with an annual estimate growth rate of 15%. Given this information, the 2000 estimated penetration rate was 12,5%. In this same report, it was stated that "there were large differences in terms of AC penetration". According tot these figures and assuming a 13% average penetration rate in 2000 (we assumed a larger penetration rate given the past trends), it was assumed that 9%, 10% and 15% were the penetration rates for single house-rural, single house-urban and multi-apartment all, respectively.

Residential Heating:
Data from Proyecto Indel (REE 1998) was used to estimate the heating load curve.

Type of building	RD	RN	RP	SD	SN	SP	FD	FN	FP	WD	WN	WP
Rsd.Space Heat.Single.Rural.Existing.	0.130	0.040	0.030	0.000	0.000	0.000	0.065	0.020	0.015	0.455	0.140	0.105
Rsd.Space Heat.Single.Urban.Existing.	0.130	0.040	0.030	0.000	0.000	0.000	0.065	0.020	0.015	0.455	0.140	0.105
Rsd.Space Heat.Multi.All.Existing.	0.130	0.040	0.030	0.000	0.000	0.000	0.065	0.020	0.015	0.455	0.140	0.105

Table 2.18: Load curve for heating systems

The curve load from this report only accounted for the electrical heating systems, but it was assumed that the consumption trends were similar for other fuels heating systems.

This report was also useful to get information that helped us define heating system technology shares for the base year (divided by building type). In particular, technology shares of electrical heating systems, the information came straight from the above mentioned report whereas for other fuelled heating systems, the information were integrated with other sources (INE 1995 and INE/IDAE, 1997). Nevertheless, some estimations based on experts opinions and sector reports were also necessary to compensate the lack of detailed data.

In few cases in which no information from Spanish sources was available, values from the Italy were used as reference since these two countries are very similar in terms of climate and socio-economic conditions. Therefore, the use of Italian figures does not introduce significant distortion to the Spanish model.

With regards to the technical and economic characterization of the technologies, the following international data sources were consulted in order to provide the necessary information required in the templates:

(i) EFDA-TIMES database

This is database that feeds a multi-regional energy model. For our purpose, only data from the Western European region was used.

(ii) GEMIS database

(iii) MURE database

The MURE database allows the user to select the country of interest and look at data for this country. This database was particularly useful, providing information –at the household level-, for all technologies in Spain.

(iv) ENERGYSTAR database

This is a North-American database that allows the user to select any appliance and calculate the energy savings you can get using the most efficient technology. For the modelling purpose, the underlying assumptions (costs, efficiencies, etc) of conventional technologies were used mainly as reference values, since the US technologies are quite different from the Spanish ones.

(v) ENEA- Risparmio Energético con gli impianti di riscaldamento (2003)

The Enea report (ENEA, 2003) on residential energy use in Italy provided the basic technical and economic parameters for the household technologies. The information was considered quite reliable because, as mentioned before, of the very similar climatic and socio-economic conditions of Italy and Spain.

Moreover, to validate the modelling assumptions and to better fit the data to the Spanish Energy system features, many other sources were consulted at the national level, among which: IDAE, University of Sevilla, ATECYR, ASEFOSAM, CONAIF, ANFEL.

At the same time, the information was also contrasted using some manufacturers´ web-pages (VAILLANT, SANIERDOUVAL, etc). Nevertheless, some of the current technical parameters have very much improved since 2000 and therefore were not representative for the base year.

Again, the Proyecto Indel report (REE, 1998) was the main source of information to estimate the cooling systems load curve. Since most of the cooling systems in Spain are electricity fuelled, the load curve from Proyecto Indel-REE provided us with a good representation of the actual load curve.

Type of building	RD	RN	RP	SD	SN	SP	FD	FN	FP	WD	WN	WP
Rsd.Space Cool.Single.Rural.Existing.	0.12	0.04	0.02	0.47	0.23	0.06	0.05	0.01	0.01	0.00	0.00	0.00
Rsd.Space Cool.Single.Urban.Existing.	0.12	0.04	0.02	0.47	0.23	0.06	0.05	0.01	0.01	0.00	0.00	0.00
Rsd.Space Cool.Multi.All.Existing.	0.12	0.04	0.02	0.47	0.23	0.06	0.05	0.01	0.01	0.00	0.00	0.00

Table 2.19: Load curve for cooling systems

The cooling systems technology shares were estimated by considering the data from Red Eléctrica (REE, 1998) on air conditioning sales (94% splits AC, 2,2% portable AC, 1,5% window AC and 1,8% without system specification). These values were further divided by rural/urban buildings as well as single house/multi family urban buildings, utilizing some estimations from Proyecto Indel (REE, 1998).

Most technical and economic parameters of the cooling systems were obtained from the same sources of data utilised for the characterisation of the heating systems. In particular, most of the information was obtained from the EFDA-TIMES model database for Western Europe and from the ENEA reports (ENEA, 2003)

Residential water heating:

As shown in table 2.20, the load curve for Residential Water Heating, was obtained from the above mentioned Proyecto Indel-REE 1997 (REE, 1998). Similar to the other uses, the technical and economic parameters were mainly obtained from the EFDA-TIMES model database, adapting the values for Western Europe to the Spanish case.

Demand	Type of building	RD	RN	RP	SD	SN	SP	FD	FN	FP	WD	WN	WP
RWRE	Rsd.Water Heat.Single.Rural.Existing.	0.2	0.03	0.025	0.2	0.025	0.03	0.2	0.025	0.025	0.2	0.025	0.025
RWUE	Rsd.Water Heat.Single.Urban.Existing.	0.2	0.03	0.025	0.2	0.025	0.03	0.2	0.025	0.025	0.2	0.025	0.025
RWME	Rsd.Water Heat.Multi.All.Existing.	0.2	0.03	0.025	0.2	0.025	0.03	0.2	0.025	0.025	0.2	0.025	0.025

Table 2.20: Load curve for water heating systems.

Other energy uses in the residential sector:

This broad category includes many domestic appliances with different load curve behaviour. Also in this case, the data was obtained from the Proyecto Indel report (REE, 1998) considering the "miscellaneous" category included in the report, since the majority of the appliances included in this category are electricity fuelled.

Demand		RD	RN	RP	SD	SN	SP	FD	FN	FP	WD	WN	WP
RLIG	Rsd.Lighting.Existing.	0.042	0.14	0.032	0.05	0.163	0.04	0.042	0.137	0.032	0.07	0.215	0.0495
RCOK	Rsd.Cooking.Existing.	0.147	0.04	0.021	0.175	0.05	0.03	0.147	0.042	0.021	0.23	0.066	0.033
RREF	Rsd.Refrigeration.Existing.	0.097	0.105	0.009	0.114	0.125	0.010	0.097	0.105	0.009	0.151	0.164	0.014
RCWA	Rsd.Cloth Washing.Existing.	0.126	0.05	0.032	0.15	0.063	0.04	0.126	0.053	0.032	0.2	0.083	0.0495
RCDR	Rsd.Cloth Drying.Existing.	0.126	0.05	0.032	0.15	0.063	0.04	0.126	0.053	0.032	0.2	0.083	0.0495
RDWA	Rsd.Dish Washing.Existing.	0.126	0.04	0.042	0.15	0.05	0.05	0.126	0.042	0.042	0.2	0.066	0.066
ROEL	Rsd.Other Electric.Existing.	0.147	0.06	0.021	0.175	0.075	0.03	0.147	0.063	0.021	0.23	0.099	0.033
ROEN	Rsd.Other Energy.Existing.	0.147	0.06	0.021	0.175	0.075	0.03	0.147	0.063	0.021	0.23	0.099	0.033

Table 2.21: Load curve for other energy uses in the residential sector.

Most of the data sources and reports mentioned above included information regarding some of the appliances included in this RO category (dishwasher, washing machine, lighting systems, etc). We reviewed and used some of the information included in those sources to complete this template sheet.

Demolition rates and temperature correction figures were updated according to national data.

2.2.1.2 Commercial:

As it was the case in the residential sector, the EUROSTAT data did not have any major discrepancy with the national data sources. The 2000 energy consumption of the commercial sector was 277 PJ. The most important fuel was electricity (with 180 PJ) followed by Oil (61 PJ) and Natural Gas (26). Biomass and LPG were also used in the commercial sector, with 2 and 9 PJ respectively.

With regards to the breakout by end use and building type (fractional shares), the following values were considered for Spain in 2000.

Breakout by end-use (Fractional Shares)										
End-use description	COMCOA	COMLPG	COMOIL	COMGAS	COMBIO	COMSOL	COMGEO	COMELC	COMLTH	COMHTH
Space Heating	0.90	0.85	0.91	0.74	0.90	0.00	0.85	0.23	0.85	0.85
Space Cooling				0.02			0.00	0.20		0.00
Water Heating	0.00	0.08	0.01	0.16	0.00	1.00	0.15	0.08	0.15	0.15
Lighting								0.10		
Cooking	0.10	0.07	0.08	0.08	0.10	0.00		0.07		
Refrigeration								0.10		
Public Lighting								0.10		
Other Electric								0.12		
Other Energy							0.00			
Total	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Breakout by building type (Fractional Shares)										
Building type	COMCOA	COMLPG	COMOIL	COMGAS	COMBIO	COMSOL	COMGEO	COMELC	COMLTH	COMHTH
Small	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Large	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Small				0.3			0.3	0.3		0.3
Large				0.7			0.7	0.7		0.7
Small	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Large	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

Table 2.22: Commercial breakout by end-use and building type

The estimations provided in the template came from different sources already mentioned in the residential section. However, one of the most important data sources for commercial is the government report *"Estrategia de Ahorro y Eficiencia energética de España 2004-2012: Sector equipamiento residencial y ofimática (residencial y servicios)"* (Ministerio de Economía, 2003) as well as Proyecto Indel (REE, 1998). Al l values estimated using those different data sources were also compared to the Italian values for a consistency check.

With regards to the statistics on stocks, official census data from the National Statistics Institute (INE, 2001) as well as Ministerio de Fomento (Civil Works ministry) was used.

Statistics on stocks: number of square meters		
	1000s	%
Small	330844	30%
Large	771969	70%
	1102813	100%
Proportion of stock with a cooling system		
	1000s	% with Cooling
Small	148879.7163	45.00%
Large	694772.0094	90.00%
	843651.7258	1.35

Table 2.23: Commercial stocks

With regards to the commercial heating/cooling/hot water and other commercial appliances, information from Proyecto Indel (REE-1998) was used in order to construct the load curve:

Demand	HEATING SYSTEMS	RD	RN	RP	SD	SN	SP	FD	FN	FP	WD	WN	WP
CHSE	Com.Space Heat.Small.Existing.	0.09	0.00	0.02	0.00	0.00	0.00	0.19	0.00	0.04	0.54	0.07	0.07
CHLE	Com.Space Heat.Large.Existing.	0.10	0.00	0.02	0.00	0.00	0.00	0.20	0.00	0.03	0.48	0.12	0.06
Demand	COOLING SYSTEMS	RD	RN	RP	SD	SN	SP	FD	FN	FP	WD	WN	WP
CCSE	Com.Space Cool.Small.Existing.	0.150	0.000	0.025	0.600	0.075	0.075	0.063	0.000	0.013	0.000	0.000	0.000
CCLE	Com.Space Cool.Large.Existing.	0.139	0.000	0.020	0.475	0.238	0.059	0.059	0.000	0.010	0.000	0.000	0.000
Demand	WATER HEATING SYSTEMS	RD	RN	RP	SD	SN	SP	FD	FN	FP	WD	WN	WP
CWSE	Com.Water Heat.Small.Existing.	0.2	0	0.05	0.2	0	0.05	0.2	0	0.05	0.2	0	0.05
CWLE	Com.Water Heat.Large.Existing.	0.15	0.05	0.05	0.15	0.05	0.05	0.15	0.05	0.05	0.15	0.05	0.05
Demand	OTHER USES	RD	RN	RP	SD	SN	SP	FD	FN	FP	WD	WN	WP
CLIG	Com.Lighting.Existing.	0.174	0.043	0.043	0.087	0.043	0.043	0.174	0.043	0.043	0.217	0.043	0.043
CCOK	Com.Cooking.Existing.	0.150	0.017	0.083	0.150	0.017	0.083	0.150	0.017	0.083	0.150	0.017	0.083
CREF	Com.Refrigeration.Existing.	0.156	0.083	0.010	0.156	0.083	0.010	0.156	0.083	0.010	0.156	0.083	0.010
CPLI	Com.Public Lighting.Existing.	0.049	0.195	0.000	0.000	0.195	0.000	0.073	0.195	0.000	0.073	0.220	0.000
COEL	Com.Other Electric.Existing.	0.150	0.017	0.083	0.150	0.017	0.083	0.150	0.017	0.083	0.150	0.017	0.083
COEN	Com.Other Energy.Existing.	0.150	0.017	0.083	0.150	0.017	0.083	0.150	0.017	0.083	0.150	0.017	0.083

Table 2.24: Load curve for heating, cooling, water heating and other commercial uses systems.

Data from the same report was used in order to estimate the technology shares. Analogously to the residential sector, technical and economic parameters were estimated by the EFDA-TIMES model database for Western-Europe and from the ENEA reports (ENEA, 2003).

2.2.1.3 Modeling remarks

In order to avoid abrupt energy and technology changes in the shorter term, adratios have been added in RSD sector (minimal relative levels of electricity, biofuels and oil products) and COM sector (minimal relative level of oil products); the allowed flexibility increases in the future.

Moreover, in order to avoid coal taking all the market (irrealistic but observed in some of our tests), an adratio limiting coal use has also been added (defined as the share of coal in the total energy consumption of sectors). Idem with geothermal in commercial.

Note also that the corrections proposed by Koen (note december 1st) were fully integrated, more particularly the addition of the second efficiency of combined technologies, which was missing; the consequence is a (expected) far smaller penetration of these technologies; a general review of the technical efficiencies of technologies will be undertaken.

2.2.2. Agriculture

The Eurostat balance for Agriculture did no present any major discrepancies with the national values. No additional values were required for the Spanish template, because, as described extensively in the Deliverable D1.4, agriculture is modelled in a very simple way.

2.2.3. Industry

2.2.3.1. Introduction

The Spanish industrial template is composed by the following sheets:

- IND_Bal, which contains the base-year information for energy consumption from EUROSTAT, data aggregated by sector fuel, breakout by industry and by energy service, and final energy consumption by industry.
- Autoprod, which holds information related base-year consumption, production and capacity installed from EUROSTAT, the breakout of CHP auto-production by industry, technologies for ELC and CHP auto-production, and base-year generic boiler information for industrial heat.
- IIS, with information related iron and steel energy demand. Especially, fractional shares of raw iron and crude steel production, base-year technologies for: finished iron and steel production, stainless steel production, ferrochrome production, crude steel production, raw iron production, and pellet and sinter production.
- IAL-ICU, which includes information related to aluminium and copper energy demand. In particular, fractional shares of crude aluminium production and secondary copper production, base-year technologies for: crude and finished aluminium production, and secondary and finished copper production.
- INF, with information related other non-ferrous metals energy demand.
- IAM-ILC, which has information related ammonia and chlorine energy demand. Particularly, fractional shares of standard and advance ammonia and chlorine production, and information associated to base-year technologies for ammonia and chlorine production.
- ICH, with information related other chemicals energy demand.
- ICM-ILM-IGH-IGF, which maintains information of cement, lime, glass-hollow and glass-flat energy demand. Specifically, fractional shares of dry and wet clinker production, glass-hollow from recycling and non-recycling sources, and proportion of clinker kilns fed by coal, natural gas and heavy fuel oil. It also contains also base-year data for technologies of: clinker and finished cement production, quick lime production, and hollow and flat glass production.
- INM, with information related other non-metallic minerals energy demand.
- IPP, which has information related to high and low quality paper energy demand. Particularly, fractional shares of mechanical, chemical and recycling pulp production, and information associated to base-year technologies for pulp, low quality and high quality paper production.
- IOI, with information related other industries energy demand.
- NEC, with information related fuels demand from non-energy consumption in chemicals production.
- NEO, with information related fuels demand from non-energy consumption in other industries.
- IND_Comm, which contains the list of established commodities in the industrial sector.
- IND_Fuel, which holds information regarding base-year and new infrastructure for industrial fuels, base-year infrastructure for industrial electricity, and base-year and new infrastructure for industrial heat.

- EMI, with the static and dymanic coefficients for combustion emissions in industry.

2.2.3.2. Energy Balance

Base-year energy consumption and aggregated data by sector fuel coming from EUROSTAT were accepted without any modification. Major entries were concentrated in Final Energy Consumption (breakout by industry and energy service) percentages. Main input data are displayed in the following tables.

The breakout of energy consumption by industry sub-sectors was made according to data from the Spanish Ministry of Economy (2003), Ecoinvent database, and the Statistical National Institute (2001). For the paper industry, total production in year 2000 was is 6.51 Mtons, out of which approximately 2,05 Mtons was quality paper. It was assumed that the energy consumption was similar for both products. Therefore energy consumption was split according to production shares. (30% and 70% aprox.).

For the breakout by energy service, there are no national sources of information for this breakout, so expert analysis and judgement were utilized.

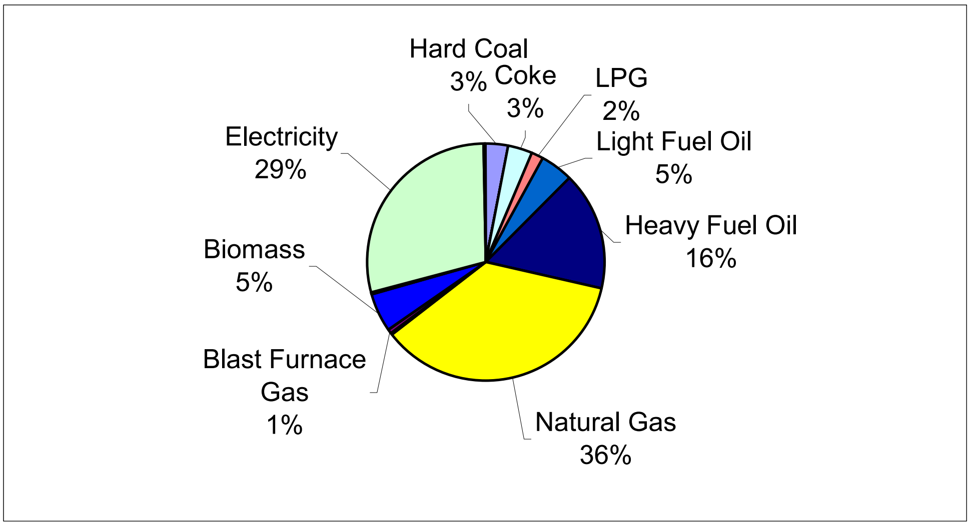


Figure 2: Fuel share for Industry (year 2000)

Industry sector	1990	2000	2004
101805 Final energy consumption Iron and steel industry	160	167	215
101810 Final energy consumption Nonferrous metal industry	41	49	65
101815 Final energy consumption Chemical industry	121	157	188
101820 Final energy consumption Non metallic mineral products industry	176	262	293
101825 Final energy consumption Ore extraction (except fuels) industry	11	15	14
101830 Final energy consumption Food, drink and tobacco industry	70	107	131
101835 Final energy consumption Textile, leather and clothing industry	36	51	43
101840 Final energy consumption Paper and printing industry	48	88	99
101845 Final energy consumption Engineering and other metal industry	55	82	103
101850 Final energy consumption Other non classified industries	105	89	134
101899 Final energy consumption Adjustment	15	0	0.4
Other industries	0	344	2
Total all industries	838	1066	1285.4

Table 2.25: Final energy consumption by industry sector 1990 and 2004 [PJ] – Eurostat

Autoproduction

Absolute numbers for CHP auto-production by fuel and industry were obtained from Ministry of Economy (Ministerio de Economía, 2003). Major discrepancies were found both in the fuel used by autoproducers (national statistic reports much higher values) and in the electricity produced (national statistics show much lower values). No attempt was made to correct these inconsistencies for the base year and the data provided from Eurostat for auto-production capacity by fuel were maintained.

Heat produced by autoproducers and consumed in the industry sector was not accounted for in Eurostat values. This heat production was calculated using the efficiencies and the CHPR factors included in the template and this heat was introduced as an input in each industrial sector consuming it in order to calibrate the model.

CHP technologies characterization

Efficiency (electrical) and heat to power ratios were derived from statistical data on fuel consumption and production for each industry.

Base year demand and technologies for industrial processes

For all industrial production technologies minor changes were made in fuel consumption declared by Eurostat to ensure harmonisation. Similarly minor changes were made in material inputs and outputs during the calibration process.

For the following sectors some specific consideration should be noted:

IIS (iron and steel)

- Demand from iron and steel industries was taken from ICEX (The Iron and Steel Products and Plant Sector), while percentages for raw iron and crude steel production technologies were taken from the International Iron and Steel Institute (Steel Statistical Yearbook 2004).

IAL (aluminium) and ICU (copper)

- Aggregated demand data for these two industries were obtained from MINECO.

IAM (ammonia) and ICM (chlorine)

- While data from ammonia demand was extracted from INE, chlorine demand was taken from the Spanish Chlorine Producers Association (ANE).

ICM (cement), ILM (lime), IGH (Glass Hollow), IGF (Glass Flat)

- Cement demand for year 2000 as well as the proportion of wet and dry clinker production was obtained from OFICEMEN. The share of clinker kilns by fuel was estimated from the same source considering that petroleum coke is included in the heavy fuel oil share.
- Lime demand was extracted from ANCADE, while the proportion of clinker kilns by fuel was estimated without any referenced data. Thus, these percentages must be refined in future documentation.
- Glass Hollow demand for year 2000 was taken from ANFEVI and the proportion of glass hollow production from recycled glass was obtained from the same source but from data corresponding to year 2004.

IPP (paper pulp)

- High and low quality paper demand was estimated from data of CEPI (2001) as well as the share of pulp production by chemical, mechanical and recycled materials. The proportion of pulp production by fuel was estracted from ASPAPEL.

IND_Fuel (infrastructures)

- The shares of base-year infrastructure for high, medium and low electricity were calculated from CNE (2002) corresponding to year 2001 data.

Other modelling remarks

Because of a too high coal penetration in industry, a user's constraint was added to limit the share of coal relatively to the total of coal and gas fuels.

2.2.4. Transport

Overall default data contained in the Balance Sheet was not altered. According to the Spanish LPG association, the stock of vehicles using LGP for year 2000 was added. Table of kilometres per vehicle and fuel was fulfilled according to the 2004 Report of the Spanish Sustainable Development and Energy Observatory (2005). Other major sources of information have been the Ministry of Fomento (2003), the Ministry of Economy (2003) and the IDEA (2003/2004).

FIXOM and VAROM data for the different ways of transport (cars, buses, road freight) were taken from ECN MARKAL data. All technologies lifetime were inserted according to existing data available. Concerning the distribution costs of new infrastructure for transport fuels, data were taken from IEA (1999).

Transport Sector	Gas (NGA + LPG)	Motor Spirit	Kerosene – Jet fuels	Diesel Oil	Heavy Fuel Oil	Biofuels	Electricity	Total
Rail				20			15	35
Road	3	375		713		3		1094
Air			188					188
Navigation + bunkers				90	216			306
Total	**3**	**375**	**188**	**823**	**216**	**3**	**15**	**1624**

Table 2.26: Final energy consumption of the Spanish transport sector in 2000 in PJ [Eurostat]

Indicator	Unit	Eurostat 2000
Passenger-kilometer cars	Million	300904
Passenger-kilometer motos	Million	14340
Passenger-kilometer buses	Million	50300
Road Freight-kilometer	Million	148700
Passenger Heavy Trains-kilometer	Million	20150
Freight Trains-kilometer	Million	11614
Passenger Light Trains-kilometer	Million	5230
Aviation Generic	PJ	188.3
Navigation Generic	PJ	305.9

Table 2.27 Transport Demand in Spain**.**

Modeling remarks

Domestic and international navigation, as well as domestic and international aviation, have been split in order to allow different emission accounting. The split is based on the 2000 IEA energy consumption. Demand projections of international navigation (bunkers, TMB) and international aviation (TAI) have been added in the Scen_Xbase.xls. Note that the inputs of these technologies are TRA*, contrary to what K. Smekens recommended, since we wanted to include these emissions in TRA sector. Any change is possible, of course.

2.3 Air emissions

2.3.1 Global warming emissions

Spain had agreed the European Union burden sharing to reach the Kyoto targets with a contribution of +15% of GHG emissions till 2012 compared to the 1990 emissions. However, despite the reduction efforts of the last years, in 2004 Spain's GHG emissions had increased by approximately 49 % compared to the 1990 emissions. In tables 2.28, 2.29, 2.30 and 2.31 the evolution of CO2, N2O and CH4 emissions, as well as total GHG emissions is shown (Ministerio de Medio Ambiente, 2006). The emissions are separated by sector of activity.

Sector	1990	2000	2004
Conversion, production	79.11821	107.23628	117.40493
Industry	66.63806	82.34961	99.48474
Households, commercial, agriculture	25.27984	33.06433	38.35848
Transport	56.51224	84.80695	99.22255
Other	1.01358	0.21592	0.09165
TOTAL	**228.56193**	**307.67309**	**354.56235**

Table 2.28 CO_2 emissions by sector in years 1990, 2000 and 2004. (Mt CO_2 equivalent)

Sector	1990	2000	2004
Conversion, production	2505.32	2087.88	1914.71
Industry	124.83	182.11	264.12
Households, commercial, agriculture	19206.98	22747.22	23567.14
Transport	240.77	217.98	193.38
Other	5388.72	9523.35	10693.41
TOTAL	**27466.62**	**34758.54**	**36632.76**

Table 2.29. N_2O emissions by sector in years 1990, 2000 and 2004. (kt CO_2 equivalent)

Sector	1990	2000	2004
Conversion, production	282.63	629.96	688.54
Industry	3650.54	3290.94	2690.51
Households, commercial, agriculture	21907.9	25971.99	24346.96
Transport	783.16	1977.73	2595.44
Other	1146.57	1157.11	1248.39
TOTAL	**27770.8**	**33027.73**	**31569.84**

Table 2.30. CH_4 emissions by sector in years 1990, 2000 and 2004. (kt CO_2 equivalent)

Sector	1990	2000	2004
Conversion, production	81.90616	109.95412	120.01222
Industry	73.76645	94.60899	107.51302
Households, commercial, agriculture	66.39472	81.78354	86.27258
Transport	57.53617	87.00265	102.01137
Other	7.54887	10.89637	12.09946
TOTAL	**287.15237**	**384.24567**	**427.90865**

Table 2.31. Total GHG emissions by sector in years 1990, 2000 and 2004. (Mt CO_2 equivalent)

The observed increase is GHG emissions is lead by the increase in emissions in the transport sector that has seen risen its emissions by a 77% from 1990 to 2004, although the other sectors have also increased significantly their emissions. Industry emissions have risen about 46 % in the same time period. The electricity generation sector also increased substantially its emissions (47 % in the same period). Figure 3 presents GHG emissions by sector from 1990 to 2004.

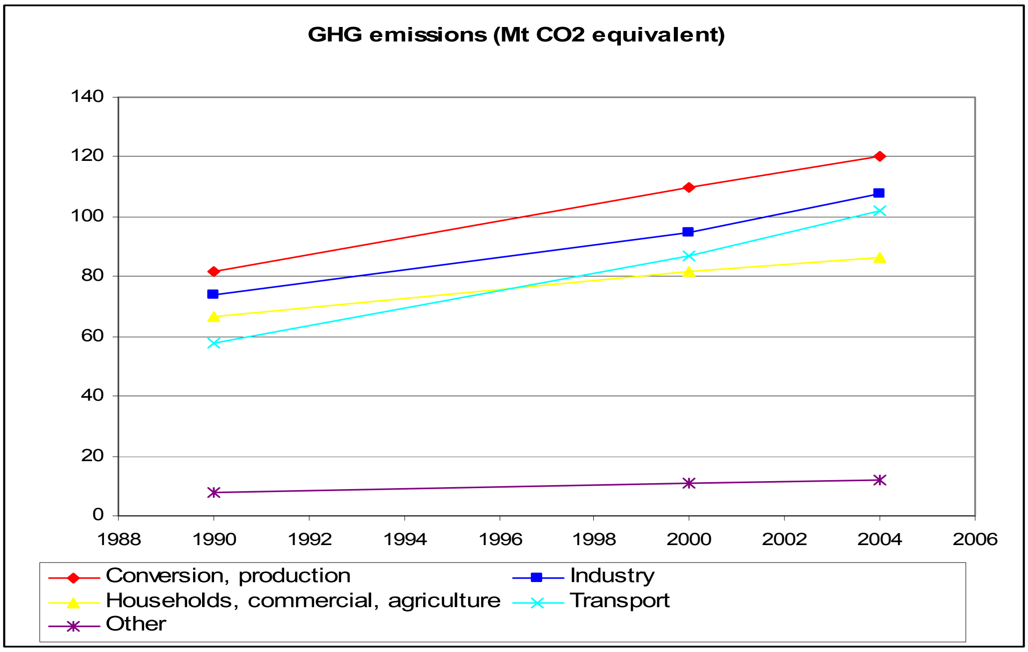


Figure 3: GHG emissions

2.3.2. Other emissions

Regarding emissions of other gases, tables 2.32, 2.33, 2.34 and 2.35 show the observed trends.

Sector	1990	2000	2004
Conversion, production	264.2	347.54	359.35
Industry	201.79	274.18	356.6
Households, commercial, agriculture	179.55	194.08	199.42
Transport	566.48	634.59	616.23
Other	4.58	3.01	3.01
TOTAL	**1216.6**	**1453.4**	**1534.61**

Table 2.32. NOx emissions by sector in years 1990, 2000 and 2004. (kt)

NOx emissions have increased by a 26% mainly due to the significant increase in the industry sector. However, a decreasing trend in observed in the transport sector in the last years. The national ceiling objective for NOx emissions is set in 847 kt by year 2010 (Directive 2001/81/CE), that means almost halving the emissions in year 2004..

Sector	1990	2000	2004
Conversion, production	21.58	24.41	28.56
Industry	468.24	522.85	598.68
Households, commercial, agriculture	717.61	591.32	542.07
Transport	2349.52	1475.98	1135.13
Other	101.63	77.52	79.66
TOTAL	**3658.58**	**2692.08**	**2384.1**

Table 2.33. CO emissions by sector in years 1990, 2000 and 2004. (kt)

CO emissions have decreased in the period from 1990 to 2004 by a 35% due to the dramatic reduction that occurred in the transport sector (52%).

Sector	1990	2000	2004
Conversion, production	71.72	79.18	76.98
Industry	574.58	569.52	741.05
Households, commercial, agriculture	79	67.19	60.7
Transport	422.39	30.74	211.94
Other	22.34	418.78	28.04
TOTAL	**1170.03**	**1165.41**	**1118.71**

Table 2.34. NMVOC emissions by sector in years 1990, 2000 and 2004. (kt)

NMVOCs emissions have been reduced in Spain, over the period from 1990 to 2004 by a 4%, mainly due to the reduction of emissions in the transport sector. However, national emission ceiling for this pollutant has been set at 662 kt. that means a significant reduction effort.

Sector	1990	2000	2004
Conversion, production	1668.48	1146.18	1066.91
Industry	363.69	239.49	203.89
Households, commercial, agriculture	60.97	46.83	33.86
Transport	84.9	45.82	54.08
Other	2.09	0.91	0.84
TOTAL	2180.13	1479.23	1359.58

Table 2.35. SO2 emissions by sector in years 1990, 2000 and 2004. (kt)

SO_2 emissions have been reduced, homogenously in all the sectors, by a 38% on average in the analysed period.

3. National energy and environmental policies:

3.1 Nuclear situation and possible moratoria:

Currently, Spain has eight operating nuclear plants. In July 1990, Spain decommissioned the Vandellós I reactor and Union Fenosa closed José Cabrera plant in April 2006. They all add up to 7,880 MW of installed capacity, representing 12% of the total power generation. In 2004, gross production amounted 63,153 GWh. Working factors are remarkable: a load factor of 90.3% and an availability factor of 92.1%. Despite the importance of Nuclear energy in the energy mix, the Prime Minister Zapatero has announced that Spain will gradually replace nuclear power with energy from renewable sources. At this moment there is great uncertainty regarding the future evolution of the nuclear industry since it is a highly sensitive policy issue which may fluctuate if the political party in power changes.

3.2 Security of Energy Supply:

The strong dependence to one gas supplier (58% Algeria) together with the scarce interconnection between European networks, leads to a high risk of undersupply under certain situations. These facts highlight the fact that security of supply is an issue of concern in Spain. New storage and re-gasification infrastructures are currently being built in order to improve security of supply. The plan is to go from the current 800000m^3 of LNG to 2700000 m^3 by 2007.

3.3 Single Iberian Electricity market MIBEL:

In January 2004, Spain and Portugal formally signed an agreement to create a pan-Iberian electricity market (Mibel). The new market will allow generators in the two countries to sell their electricity on both sides of the border. The country ´s two energy market regulators, Spain´s OMEL and Portugal´s OMIP, will merge to create a single operator for the integrated electricity market. Repeated delays have plagued the implementation of Mibel, though the official lunch date is now July 1, 2006.

3.4 Plan de Energías Renovables (P.E.R) 2005-2010:

Based on environmental and energy security concerns, the government launched a Renewables Energy Plan 2005-2010 (I.D.A.E, 2006). The P.E.R. was officially approved on the 26th of August, 2006 and it was based on the previous report "Plan de Fomento 200-2010".

Some of the most relevant goals of the plan include: 12% of the total consumed energy from Renewables, 30% of the total electricity produced from Renewables and achieve a 6% of biofuels contribution to the total transport fuel consumption. Table II shows all the goals included in the P.E.R.

PLAN DE ENERGÍAS RENOVABLES EN ESPAÑA 2005-2010							
Electricity generation	**2004 situation**			**Goal for 2010**			% INCREASE
	POWER (MW)	PRODUC (GWh)	KTEP	POWER (MW)	PRODUC (GWh)	KTEP	MW
Hydraulic (>50Mw)	13521	25014	1979	13521	25014	1979	0%
Hydraulic (10-50 Mw)	2897	5794	498	3257	6480	557	12%
Hydraulic (<10 Mw)	1749	5421	466	2199	6692	575	26%
Biomass	344	2193	680	2039	14015	5138	593%
Biomass centrals	344	2193	680	1317	8980	3586	
Co-combustion	0	0	0	722	5036	1552	
SUR	189	1223	395	189	1223	395	0%
Wind	8155	19571	1683	20155	45511	3914	249%
Solar P.V.	37	56	5	400	609	52	1081%
Bio-gas	141	825	267	235	1417	455	167%
Thermosolar				500	1298	509	500%
TOTAL	27032	60096	5973	42494	102259	13574	157%

Table 3.1: Plan de Energías Renovables 2005-2010

The goals included in the P.E.R. report will be achieve through a range of new and modified policy instruments. Some of these policy instruments include the Renewable Energies´ feed-in tariffs which are displayed in the following table:

REN feed-in tariffs in year 2005		
	cEuro/kWh	Public support period (years)
CHP	1.44-2.88	10
Solar PV	18.74	25
Solar thermal	18.74	25
Wind	3.6	5 or 15
Geothermal	3.6	20
Mini-Hydro	3.6	15
Biomass	2.88-3.6	20
Waste	2.16	15
CHP for waste treatment	1.44-2.16	15

Table 3.2: REN feed-in tariffs in 2005

An example of the effect that such policy could generate is the evolution of wind power in Spain. Currently, Spain is the world´s second-largest producer of wind power in 2005, behind Germany. Spain has some 8,300 MW of installed wind capacity, with an additional 45,000 MW in various stages of planning development and regulatory approval.

Another important policy instrument that will be implemented in Spain is the tax exemption for biofuels. Such initiative has been put in place in order to achieve the goal of 5,85% of biofuels share in all transportation fuel consumption.

This energy plan as well as the installed capacities of wind and gas power plants are translated in adratios in the electricity sectors and the transportations sectors. However, given the uncertainties surrounding any future targets such as those of the National Energy Plan, it is considered that only 60% of the objective will be reached in 2010.

3.5 Climate Strategy

Spain ratified the Kyoto Protocol, which limited the country to increase its GHG emissions by 15 % over the 1990 level by 2012, according the EU burden-sharing agreement.

In order to achieve the Kyoto target, the Inter-ministerial Climate Change Group – which was created in May 2004-, has drawn up the National Allocation Plan (NAP) for the period 2005-2007. This plan states the total quantity of allowances that the country intends to allocate over this period and how it proposes to allocate them. This NAP has been approved by the Royal Decree 1866/2004 dated September 7th. The initial objective in this NAP is for Spain's emissions to stabilize at the average for the last three years (2000-2002). The additional reduction effort will come into play in 2008-2012 period. During this period, the emissions average must not exceed 1990 emissions by more than 24%, a percentage arrived at by combining the limitation objective for Spain under the Kyoto protocol (15%), the estimate for absorption by sinks (2%) and the international market credits (7%).

In July 2006, the Ministry of Environment published a proposal of NAP for the period 2008-2012 (Ministerio de Medio Ambiente, 2006). The objective in this period is that the total GHG emissions over five years period do not exceed five times the base year's emissions in more than 37%. The total amount of emissions allocated to the affected sectors is 152.66 Mt, 71,89 Mt to the energy supply sector and 72,81 Mt to the industry sector with a reserve provision of 7.96Mt for new installations. These quantities imply a 19.6% reduction compared to the 2005 emissions.

3.6 Spanish Strategy of Energy Saving and Efficiency E4 (Estrategia de Ahorro y Eficiencia Energética en España 2004-2012. E4. Plan de Acción 2005.2007.)

Spain has a real potential in energy efficiency improvements. Towards this objective, the Strategy of Energy Saving and Efficiency in Spain 2004-2012 Action Plan 2005-2007 (Ministerio de Industria, Turismo y Comercio, 2005) was published in July 2005**.** In this document an efficiency scenario has been designed. The energy saving targets and the associated reduction in CO2 emissions are shown in Table 3.3.

Sectors	**2005-2007**	**2005-2007**
	Energy savings (ktoe)	**CO2 avoided emissions (kt)**
Industry	1014	2442
Transport	5277	14483
Residential and Commercial (space heating, cooling, water heating and lighting)	1505	3989
Residential (electrical appliances)	905	2437
Public services (public lighting and water treatment)	191	515
Agriculture	64	175
Energy supply	3051	8424
	12007	**32465**

Table 3.3 Energy saving targets and associated CO2 avoided emissions of the E4 in the period 2005-2007.

4. The BAU scenario

4.1. Main assumption of the BAU scenario

The main assumptions were reported in each section of the description of the energy situation of Spain. The specific modeling remarks are copied here.

Trade of energy except electricity

- Imports/exports of coal and biomass commodities from European countries (eg. IMPCOAHARD from Europe) and those from Non-European countries (eg. IMPCOAHARA from South Africa) have been made distinct, so that the former can be converted in endogenous trade in the Pan-European model, and the latter kept as exogenous trade.
- Oil products and gas trade were finally modeled in a different manner, using IMP*Y and EXP*Y, since the Pan-European model will use a specific module to compute them.
- Current and future import prices have been adjusted in the Scen.Xbase.xls file. The growth of the projected prices is the same as the one proposed by Markus.
- The overall level of imports is allowed to increase by a factor 5 until year 2005. Remind that oil and gas, whose import capacity depends on pipelines and therefore can not be "freely" increased, are not concerned by this increase since they are modeled in a separated manner.
- Delivery costs of energy commodities have been calculated and added in Scen_Xbase.xls file. They apply to the final end-use technologies and not the fuel technology as suggested by Markus, since no clear agreement seems to have been reached as regards this decision. Therefore, it must be reminded that the sector fuels DO NOT reflect the delivery costs. Only the final demands do.

Trade of electricity

- The international exchanges of electricity were obtained from national statistics (REE, 2001). These values differ considerably from Eurostat data, and were therefore introduced in the supply templates replacing Eurostat data. Electricity trade prices were set taking into account the information contained in (AEAT, 2005). Import price was considered to be 9.35 Euro/GJ and the export price 10.51 Euro/GJ.
- Net international trade is considered to be constant over the horizon in the national models since any import should be reported in another country's model. Remind that electricity will be endogenously traded in the Pan-European model. The use of the national model in a standalone manner for specific policy analysis should therefore define different scenarios, given the crucial role of future electricity trade.

Residential and commercial

- In order to avoid abrupt energy and technology changes in the shorter term, adratios have been added in RSD sector (minimal relative levels of electricity, biofuels and oil products) and COM sector (minimal relative level of oil products); the allowed flexibility increases in the future;
- Moreover, in order to avoid coal taking all the market (irrealistic but observed in some of our tests), an adratio limiting coal use has also been added (defined as the share of coal in the total energy consumption of sectors). Idem with geothermal in commercial.

- Note also that the corrections proposed by Koen (note december 1st) were fully integrated, more particularly the addition of the second efficiency of combined technologies, which was missing; the consequence is a (expected) far smaller penetration of these technologies; a general review of the technical efficiencies of technologies will be undertaken.

Industry
Because of a too high coal penetration in industry, a user's constraint was added to limit the share of coal relatively to the total of coal and gas fuels.

Transport
Domestic and international navigation, as well as domestic and international aviation, have been split in order to allow different emission accounting. The split is based on the 2000 IEA energy consumption. Demand projections of international navigation (bunkers, TMB) and international aviation (TAI) have been added in the Scen_Xbase.xls. Note that the inputs of these technologies are TRA*, contrary to what K. Smekens recommended, since we wanted to include these emissions in TRA sector. Any change is possible, of course.

4.2. Main results of the full time horizon

The calibration process for the Spanish model resulted in a reasonable calibrated model which gave the following results for the BAU (Business as usual) scenario. However, it is worth mentioning that the templates with which we have run the national model could be further refined. Keeping in mind this limitation, the results from the BAU scenario seem to be quite reasonable and consistent with the actual trends from 2000 to 2005 (except for some values that will be highlighted below). Again, it is important to mention that results and assumptions should be taken with precaution since it is a work still in progress.

Several assumptions were made regarding the use of renewable energies in electricity generation and transport sectors. The actual penetration rate of these technologies in years 2001 and 2005 were introduced in the model as a constraint, and the objectives of the PER *(Plan de Energías Renovables 2005-2010)* for the year 2010 were considered as a minimum bound considering that only 60% of the objectives would be reached in 2010. Similarly, the investments made in the country on natural gas combined cycle power plants, which did not exist in the base year, were modelled through minimal activity level for the years 2001 until 2020. Finally, the use of coal in the residential and commercial sectors were restricted in the whole time horizon since the country is making an effort to replace all the coal-based heating systems to gas or diesel devices. Adratios were incorporated in the short term in order to avoid abrupt changes in the energy balance.

4.2.1. Primary energy

The evolution of total primary energy consumption over the first period (2000-2005) is underestimated compared to what has been observed in reality (according to Eurostat values, total primary energy supply in 2004 amounted 6151 while the model predicts a primary energy consumption in 2005 of 4674 PJ). Over the first period, the predicted shares among different fuels present some discrepancies with reality. Coal and natural gas consumption are underestimated by the model and oil use is overestimated. *This decrease in 2005 affects most of the results and deserve more analysis (eg. adjust the efficiency of new technologies).*

After 2010, primary energy consumption follows an ascendant path, based mainly in the use of oil, nuclear energy and coal. From this primary energy consumption, imported energy accounts for approximately 90% over the full time horizon.

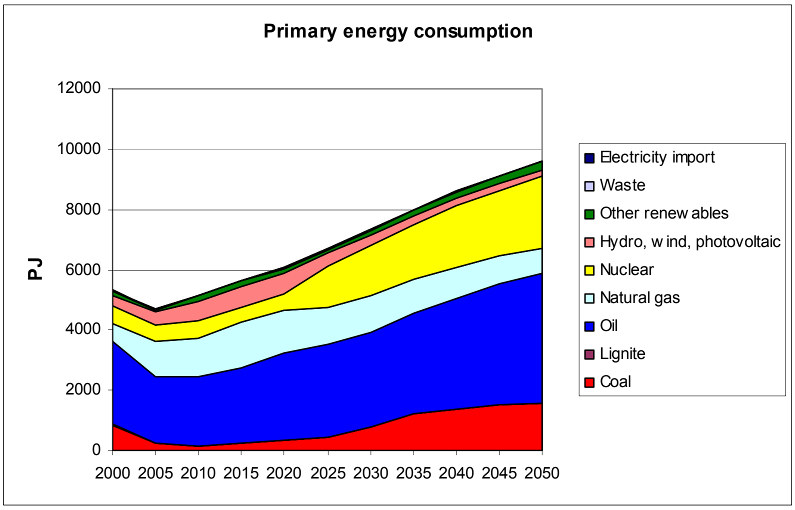


Figure 4.1. Primary energy consumption

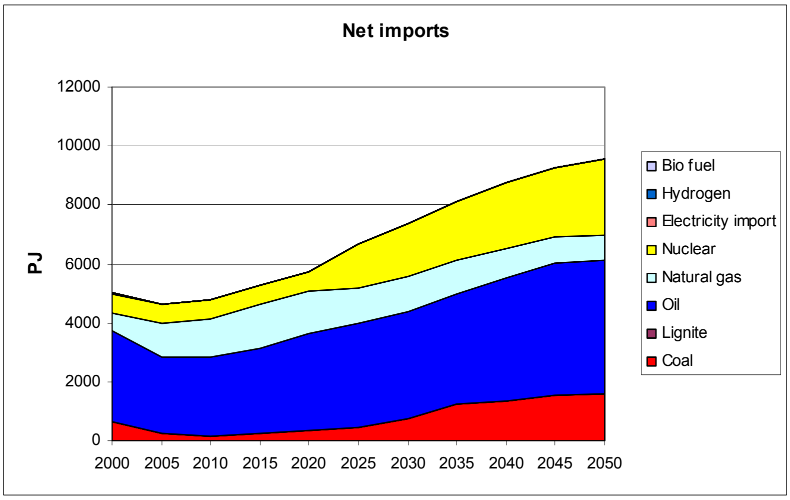


Figure 4.2. : Net imports of primary energy

4.2.2 Electricity and heat generation

The evolution of the total installed capacity for electricity generation is underestimated by the model for the year 2005. Coal power plant installed capacity is overestimated, while lignite installed capacity is greatly underestimated. Wind capacity is underestimated in 2 GW and CHP installed capacity is underestimated in another 2 GW.

The observed trend in the whole time horizon shows an increase in the net installed capacity for electricity generation during 2005 to 2010, followed by a consistent decrease in the total figures. After year 2015, nuclear capacity increases remarkably (which is consistent with the start of the advanced nuclear reactors operations). Over the last periods, all the electricity is produced by nuclear power plants, the remaining hydro capacity and a slight proportion of coal.

The sharp decline in the electricity produced from power plants from 2000 to 2005 (not observed in reality in Spain) is related to the issue raised before. The actual level of electricity production in 2004 is 246 TWh while the level predicted by the model in 2005 is 185 TWh.

Nuclear electricity plays a very important role from 2015 on, meaning it is cheaper than other form of power plants. This could be consistent with the new generation nuclear reactors start of operation. Given this huge expansion of nuclear-origin electricity production, the other sources are displaced. *Such a result indicate that the comparison of nuclear electricity and other forms of electricity would deserve more analysis. Moreover, future nuclear policies are very uncertain (social acceptablity versus low emission energy targets), and sensitivity analysis related to the level of nuclear based electricity are required, not only for Spain but for all Europe.*

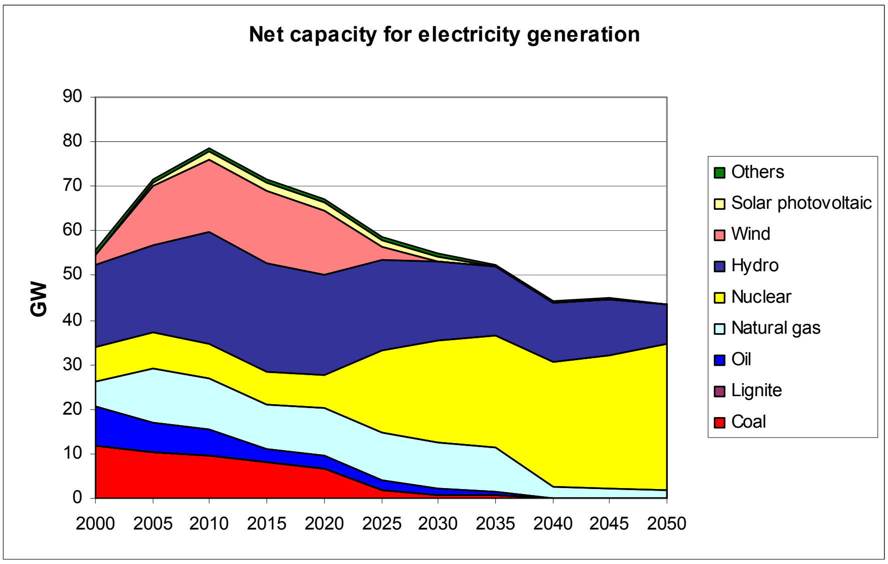
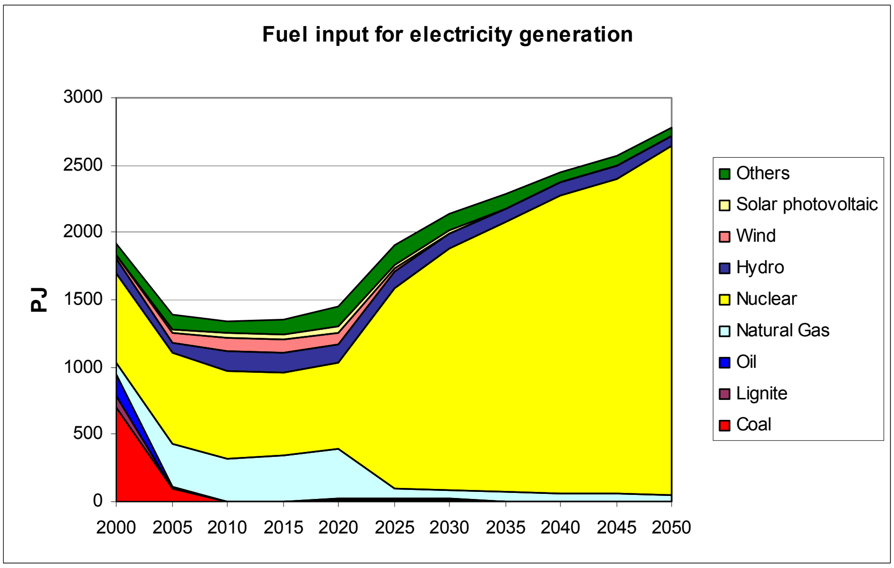


Figure 4.3 Net capacity for electricity generation



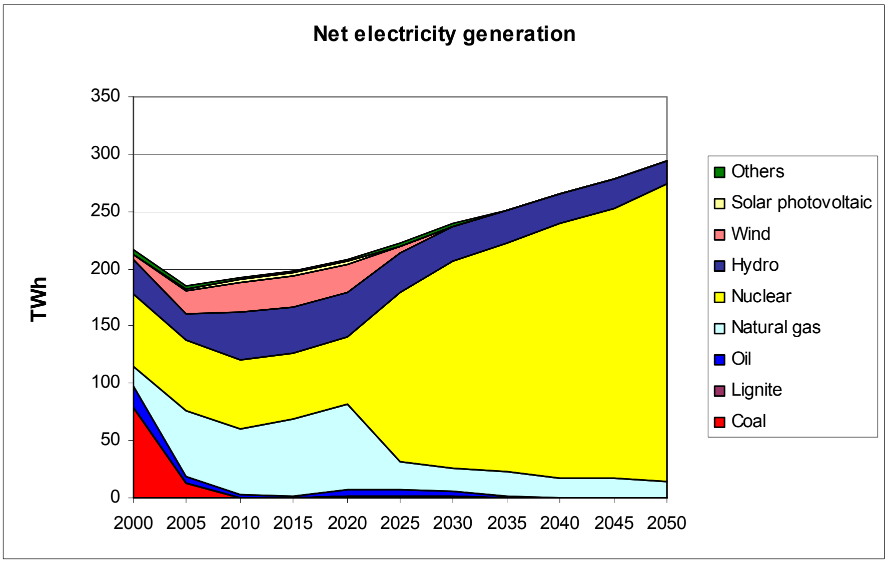


Figure 4.4 Fuel input and net electricity generation

Regarding heat generation, the increase is dominated by the industrial heat power plants. Note that industrial coal CHP has been limited (user's constraint) in order to avoid a (too) large and unrealistic penetration of such technologies.

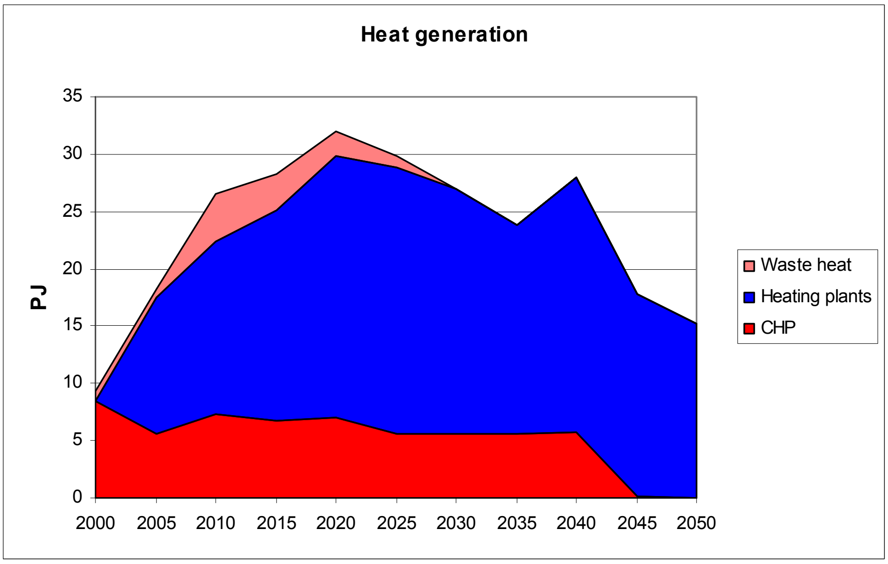


Figure 4.5 Fuel input and heat generation

4.2.3. Final energy demand

Final energy consumption shows a smooth evolution up to 2050 with a special increase in the petroleum products consumption (transport sector). Compared to actual 2005 figures, total final energy consumption is underestimated (same issue as the one identified before). Coal, electricity and renewable consumption are underestimated, while gas is slightly overestimated.

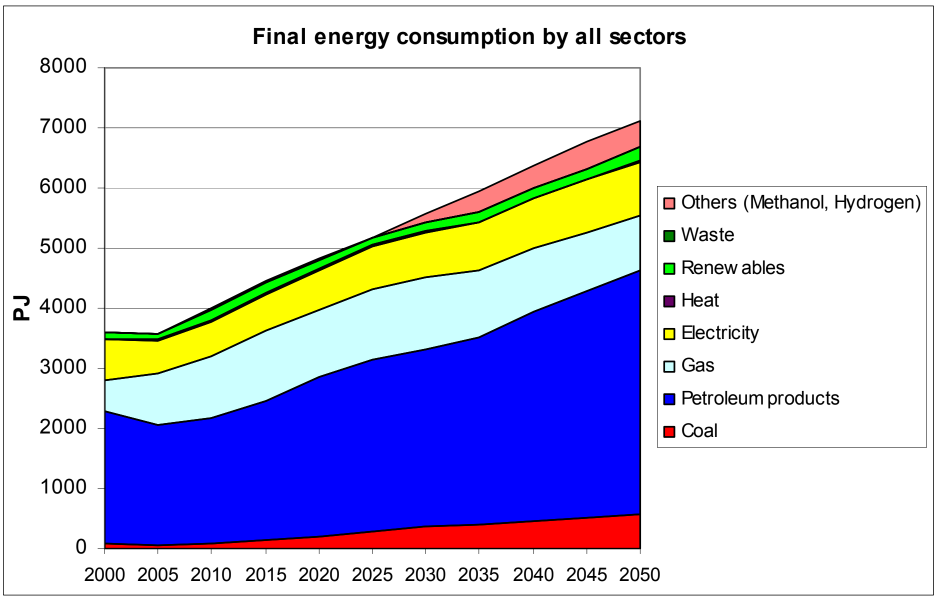


Figure 4.6. Fuel consumption by all sectors

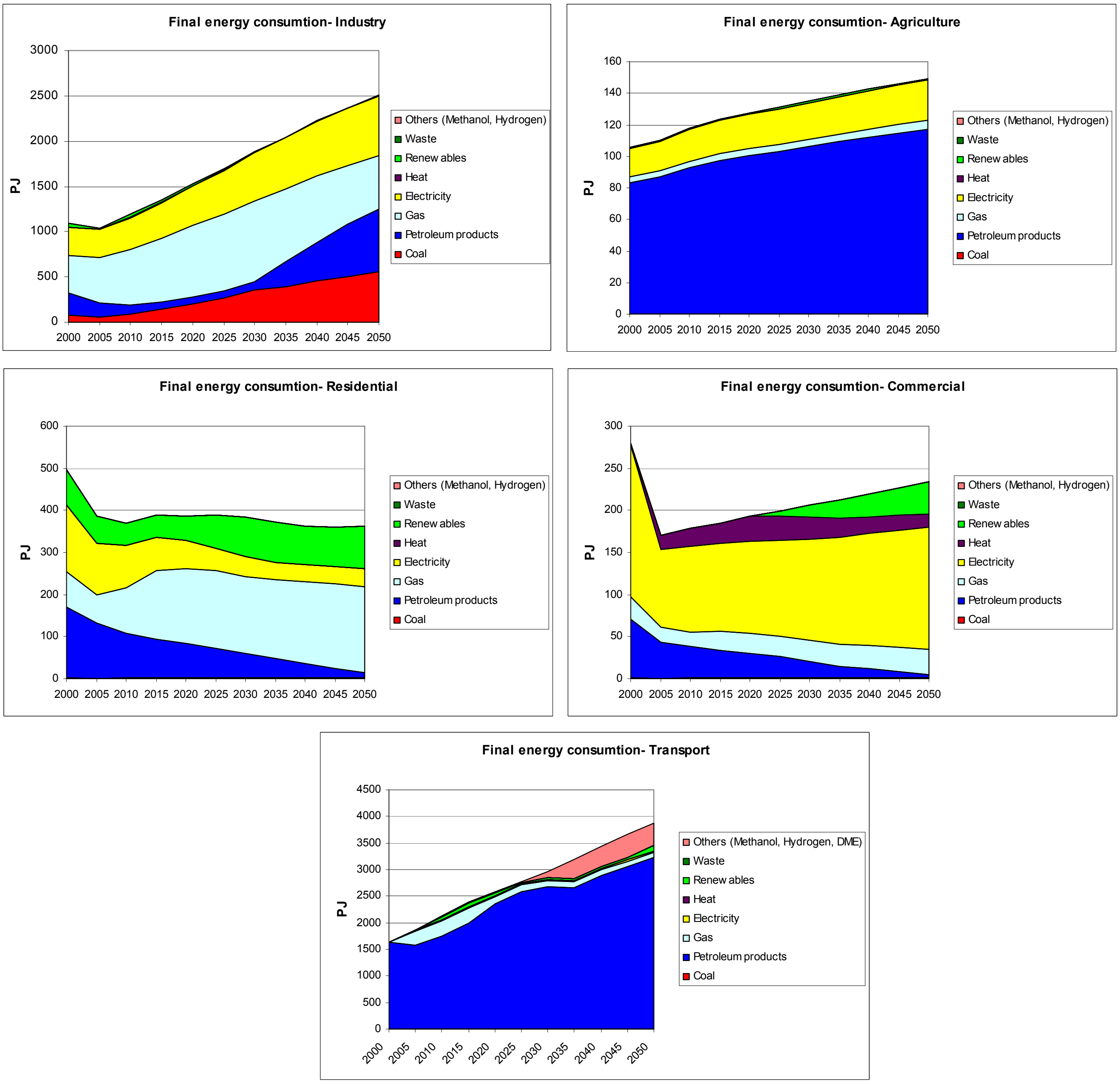


Figure 4.6: Final energy consumption in each sector

A decrease of energy consumption is observed in 2005 in the commercial and residential sectors (as well as a slight decrease in the long term in residential sector), resulting in an underestimated final energy consumption in these sectors compared to reality. A deeper analysis of technology efficiencies will be undertaken. Gas and electricity are the respective preferred fuels of residential and commercial sectors. Both of them are important in industry, while petroleum products remain the most important fuels in transportation (in the latter, 2005 consumption is slightly higher than the observed consumption).

4.2.4. Air emissions

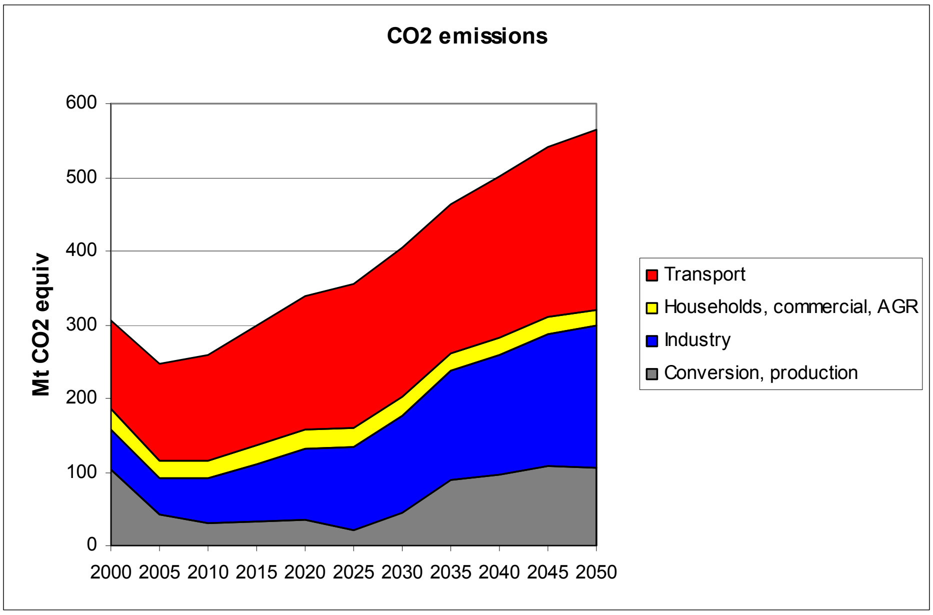


Figure 4.7 CO2 emissions

The distribution of CO2 emissions by sector shows some discrepancies with the actual 2004 values. For example, emissions from the conversion sector are underestimated by 71 M, which corresponds to the decrease of total electricity production (and consumption) between 2000 and 2005 in the results, contrary to the observed tendency. This deserves further analysis. In the future, emissions from electricity sector remains low given the high share of nuclear electricity, as noted previously.

Emissions associated to the industry and transport sectors increase considerably over the whole time horizon, due to the respective increase in the transportation demands and the use of petroleum product based technologies to meet this demand, as well as the increase consumption of coal by industry, mainly in non-metallic and other industry sub-sectors, as well as iron-and-steel and CHP to a lesser extent.

Although not shown here, it must be noted that non-CO2 emissions are not yet included in the set of new technologies of residential sector.

5. Conclusions and recommendations

Developing a technology model such as MARKAL is data and time consuming. However, the model then opens the door to many long-term analyses (energy policies, environment policies) which prove to be very useful for decision-makers given the high level of technologies in the model.

The current version of the Spanish model reflects, as far as possible, the 2000 (and 2005) energy situation of Spain. The future energy balance of Spain will depend highly on some crucial factors, as illustrated by the analysis of the numerous base case scenarios we studied:

- The international trade of electricity;
- The future national nuclear policy (no limit was assumed in the base case);
- The penetration of the future energy plan (2010) and any later energy or environmental plan.

These uncertainties deserve sensitivity analyses in any future work.

Among the other modeling aspects of the Spain model, it must be reminded that:

- Delivery cost apply to the final end-use technologies and not the fuel technology as suggested by Markus, since no clear agreement seems to have been reached as regards this decision. Therefore, it must be reminded that the sectoral fuels of the Spanish model currently DO NOT reflect the delivery costs. Only the final demands do.
- International trade of commodities separates exchanges with European countries and exchanges with Non-European countries, in order to facilitate the building of the Pan-European model.
- International aviation and navigation are included, and their demands are in Scen_Xbase.xls. They consume TRA* commodities, which could be replaced by OIL* depending on the way we want to report emissions.
- It appears crucial that the characteristics of the new technologies can be regionalized, given the possible differences in both economic and economical characteristics of technologies. A simple example is Wind power plants, given the variation of wind quality from one country to another one.
- The set of new technologies for the residential and commercial sectors could be reviewed in the next few weeks (efficiencies, modelling of the decentralized heating systems, non-CO2 emissions in residential sector).
- The decrease of energy consumption at the beginning of the horizon must be explored and better understood.

6. References

AC_Nielsen Mohezcan- Informe sobre Consumo Doméstico de Energía (2003).

CIEMAT. Centro de Investigaciones Energéticas Medioambientales y Tecnológicas. Personal comunication, (2005)

CIEMAT - Eusutel draft report "WP1: Country-wise analysis for EU-25. Spain". (2005)

CNE. Comisión Nacional de la Energía. Personal communication (2005)

CNE - El consumo electrico en el mercado peninsular en el año 2001. Comisión Nacional de la Energía, Madrid. (2002)

Confederation of European Paper Industries -'CEPI Annual Statistics 2000' (2001)

ENEA- Risparmio Energético con gli impianti di riscaldamento (2003)

European Parliament - Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on National Emission Ceilings for Certain Atmospheric Pollutants (2001)

Foro Nuclear. Energía 2006. (2006)

Greenpeace. Renovables 2050. Un informe sobre el potencial de las energías renovables en la España peninsular. (2006)

IDAE. Prospectiva energética y CO2 . Escenarios 2010. (2000)

IDAE. Plan de Energías Renovables 2004-2010 (2006)

IDAE. Eficiencia energética y energías renovables 7. Septiembre 2005. (2005)

IDAE - Energy Efficiency and Renewable Energies. IDAE Bulletin nº 5 and 6. Madrid. (2003/2004)

IEA-AFIS - Automotive fuels for the future – The search for alternatives. International Energy Agency (1999)

INE – Consumo de Energía de los Hogares -Año de Referencia 1995. Documentos de trabajo 4/99 (1999).

INE – Censo de Población y viviendas 2001 – (2002)

INE - Encuesta nacional de productos industriales 2000. Instituto Nacional de Estadística, Madrid (2001)

Loesoenen, P. Combined Heat and Power (CHP) Plant Statistics in the EU, 2000. Eurostat (2003)

Ministerio de Economía – Estrategia de Ahorra y Eficiencia Energética en España 2004-2012. Sector Equipamiento Residencial y Ofimática /Residencial y Servicios. (2003).

Ministerio de Economía - Energy Efficiency Strategy in Spain 2004-2012. Madrid. (2003)

Ministerio de Economía - Informe sobre la energía en España. Ministerio de Economía, Centro de Publicaciones, Madrid (2001).

Ministerio de Economía - Planificación de los sectores de electricidad y gas. Ministerio de Economía, Direccion General de Política Energética y Minas. (2002)

Ministerio de Economía. La Energía en España 2002. (2003)

Ministerio de Fomento - 2002 Statistical Yearbook. Madrid. (2003)

Ministerio de Industria Turismo y Comercio. Estrategia de Ahorro y Eficiencia Energética en España 2004-2012. E4. Plan de Acción 2005.2007. http://www.mityc.es/Desarrollo/Seccion/EficienciaEnergetica/Plan/

Ministerio de Medio Ambiente. Inventario de Emisiones de gases de efecto invernadero de España años 1990-2004. Comunicación a la Comisión de la Unión Europea. (2006)

Ministerio de Medio Ambiente.. Plan Nacional de asignación de derechos de emisión 2008-2012. Propuesta 12 de julio de 2006. http://www.mma.es/portal/secciones/cambio_climatico/ (2006)

OECD. “Projected cost of generating electricity” (1998)

Ordecsys, KanORS, Haloa and Kul. EFDA World Times Model. Final Report. (2004).

Perez Arriaga J.I., Hierro Ausin I- Informe Anual del Observatorio de Energia y Desarrollo Sostenible. Cátedra BP de Desarrollo Sostenible de la Universidad Pontifica de Comillas, Madrid. (2005)

Red Eléctrica de España- Proyecto Indel. Atlas de la Demanda Eléctrica Española 1997. Programa de Investigación y desarrollo electrónico PIE. (1998).

REE. Red Eléctrica de España. El Sistema Eléctrico Español. Informe 2000. (2001)

UNESA. Asociación Española de la Industria Eléctrica. Personal comm. (2005)

Websites and databases:

AEAT. Agencia Tributaria. (http://www.aeat.es/)

Asociación Nacional de Productores de Cloro. (http://www.cloro.info)

Agrupación de Fabricantes de Cemento de España. (http://www.oficemen.com)

Asociación Nacional de Productores de Cal. (http://www.ancade.es)

Asociación Española de Fabricantes de Pasta, Papel y Cartón. (http://www.aspapel.es)

Asociación Nacional de Empresas de Fabricación Automética de Envases de Vidrio. (http://www.anfevi.com)

Ecoinvent Database (www.ecoinvent.ch)- Swiss Federal Office – Swiss Center for Inventory of Life cycle analysis. (2005)

EFDA (European Fusion Development Agreement)-TIMES database global multi-regional model data base. 2004. (consulted on September/October 2005). (https://www.efda.org/eu_fusion_programme/socio_economic_research.htm)

EIA, 2005. DOE Energy Information Administration http://www.eia.doe.gov/emeu/international/gasproduction.html (last search september 2005)

Globales Emission-Modell Integrierter Systeme (GEMIS) - GEMIS DATABASE version 4.3 (September 2005). (http://217.115.141.150/service/gemis/de/index.htm)

MURE II Database – Mesures d´utilization rationelle de l´energie. (ISIS- Institute for the study of the integration of systems. Consulted on October 2005. (http://www.isis-it.com/mure/)

ENERGYSTAR database – EPA and DOE (U.S. Environmental Protection Agency and U.S. Department of Energy) (http://www.energystar.gov/index.cfm?c=home.index) (October 2005).

ENEA- Ente per le nuove technologie, l´energia e l´ambiente. (Italian Goverment) (http://www.enea.it/) (September 2005).

EUROSTAT, 2006. http://epp.eurostat.ec.europa.eu (last search August 2006)

IGME, 2006. Instituto Geológico y Minero de España. http://www.igme.es/internet/RecursosMinerales/indexc.htm (last search August 2006)

Instituto para la Diversificación y el Ahorro de la energía (I.D.A.E.). Ministerio de Industria, Turismo y Comercio. (www.idae.es). Septiembre-Diciembre 2005.

MITYC. (http://www.mityc.es/Balances/Seccion/Publicaciones/) (last search September 2005)

REE, 2006. Red Eléctrica de España. http://www.ree.es (last search august 2006)

Saunier-Douval (http://www.saunierdouval.es). September 2005.

Vaillant (http://www.vaillant.es/Web/Home.jsp) September 2005.

VIEWLS. (www.viewls.org). (last search September 2005)

Abbreviations:

AEAT: Spanish Foreign Trade statistics
ANFEL: National Association of electrical appliances manufacturers.
ANE: Asociación Nacional de Productores de Cloro.
ANCADE Asociación Nacional de Productores de Cal. (http://www.ancade.es)
ANFEVI: Asociación Nacional de Empresas de Fabricación Automética de Envases de Vidrio.
ASEFOSAM: Association of professionals working in the plumbing, sanitation, cooling heating and maintenance sector.
APAPEL: Asociación Española de Fabricantes de Pasta, Papel y Cartón.
ATECYR: Spanish Association of Heating and Cooling systems installation.
CONAIF:National association of plumbing sanitation, cooling, heating and maintenance.
CNE. National Energy Commission.
IDAE : Institute for Energy Saving and Diversification.
IGME: Spanish Geological and Mining Institute
OFICEMEN: Agrupación de Fabricantes de Cemento de España.
REE: Spanish electrical network.
UNESA: Spanish Utilities Association