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CHARACTERISATION OF POWER GENERATION OPTIONS FOR THE 21ST CENTURY

Report on behalf of Macro task E1

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Preface

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Abstract

This report gives an overview of power generation options in the MARKAL model for Western Europe. This model has been used for the evaluation of the economic potential of fusion power in Western Europe in the 21st century. Such an evaluation was part of the so-called SERF programme of the European Union (DG XII). The economic potential of fusion power, as analysed by ECN Policy Studies, is reported in the macro task SE0, which addresses long term scenarios. The present report describes the power generation options included in the model of the Western European energy system, on behalf of macro task E1, cost of fusion. The cost data are expressed as ECU of the year 1995.

CONTENTS

SUMMARY

This report contains data on power generation options used in the MARKAL model for Western Europe MARKAL-EUROPE 2.0. The MARKAL model has been used for the evaluation of the economic potential of fusion power in the 21st century. This overview of the power generation options in the MARKAL model is part of macro task E1 (cost of fusion). Macro task E1 is one of the five macro tasks in the framework of socio-economic studies of the so-called SERF programme (Socio Economic Research on Fudion) on behalf of the European Union (DGXII). The economic potential of fusion power, as analysed by ECN Policy Studies [1], is reported in the macro task SE0, which addresses long term scenarios. Investment costs are presented in ECU of 1995 and are based on a discount rate of 5% (a higher discount rate means a higher investment cost due to interest during construction).

In Chapter 2 fission and fusion power are presented in some detail, notably:
- Light Water Reactor (LWR, fission power),
- some commercial fusion power plant assumed available from 2050 on.

Chapter 3 presents a number of fossil fuel based power generation options, such as:
- pulverised coal-fired power,
- lignite-fired power,
- oil-fired power,
- gas-fired power,
- Conventional technologies, and advanced fossil fuel based options are considered.

Chapter 4 contains renewable power options: hydro power, wind power, solar power, wave power, tidal power, geothermal power, and waste-to-energy power plants. At last, comprehensive figures on power generation costs are presented in Chapter 5.

1. INTRODUCTION

This report contains tables with data on power generation technologies used in the MARKAL model for Western Europe which has been made used for the evaluation of the potential of fusion power in the 21st century. The reference discount rate is 5%, although two comprehensive figures of generation costs are presented based on a discount rate of 8%. The tables presented have been derived from a spreadsheet which includes similar investment cost data for discount rates of 5, 8, and 10%, in addition to a similar figure based on a discount rate of 5%. All power generation options with a construction schedule of more than one year show differences in investment costs as a function of the discount rate used, because of Interest During Construction (IDC). The reference currency is the ECU of year 1995.

2. FISSION AND FUSION POWER

2.1 Introduction

Fission power as we know it today delivers about 17% of the electricity generated in the world. Most of the nuclear power plants have been built in the western world. There are a few options for fission power, the most well known being the Light Water Reactor (LWR).

Fusion power is a long term power generation option with characteristics which are very different from fission power:

- Little long living radioactive waste: decommissioning waste of fusion reactors is only a fraction of the long living radioactive waste of fission reactors.
- No probability of core melt accidents or other serious accidents which can occur with fission power plants.
- A virtually inexhaustible and CO_2 free energy source.

Fusion power is in the R&D stage today. It is envisaged that fusion power could enter the demonstration stage around 2020-2030, and the commercial stage around 2050.

Data on the LWR are presented in Section 2.2. Section 2.3 contains data on a commercial fusion power plant, assumed to become available around 2050.

2.2 Fission power

About 30% of the Western European power production is based on fission power. Western European power generating companies operate almost exclusively LWRs, with as a main exception gas-cooled reactors in the UK (relatively small Magnox reactors as well as larger AGRs, Advanced Gas-cooled Reactors). However, also the UK has turned to the LWR since their first reactor of this kind, Sizewell-B. Gas-cooled reactors (AGRs) are regarded as less economic than LWRs.

Light Water Reactors (LWRs) are Pressurised Water Reactors (PWRs) or Boiling Water Reactors (BWRs). An alternative to the LWR would be the helium-cooled High Temperature Reactor (HTR). Because of their high operating temperature, enabled by the coolant helium, their low power density, and specific fuel design, HTRs are rather efficient compared to LWRs with respect to thermal efficiency (45-50% for HTRs, 33-35% for LWRs). What is more, HTRs have a very large safety margin and are far from prone to loss-of-coolant accidents and other possibly dangerous accidents. Large demonstration HTRs of some 300 MWe have been built and operated in Germany and the US. However, their operating experience proved to be not very favourable. Modular HTRs with capacities of 80 to 250 MWe have been proposed in the past ten years. The South African utility Eskom has decided to build a demonstration HTR of 110 MWe (265 MWth), based on the German ‘pebble-bed’ design. In the framework of the evaluation of fusion power it was deemed not appropriate to incorporate an HTR in the model of the Western European energy system, as there is no clear evidence that HTRs would be favoured and would result in lower power generation costs than LWRs.

Another alternative to the LWR would be a liquid-metal-cooled Fast Breeder Reactor (FBR). This reactor type is very efficient with respect to the resource uranium (some 60 times more efficient than the LWR). However, the liquid-metal Fast Breeder Reactor has safety characteristics which are less favourable than those of LWRs. Moreover, they need reprocessing of uranium and plutonium on a large scale, which induces risks of proliferation. Operating experience with demonstration FBRs has been unfavourable. Because there seems to be insufficient public acceptance for an FBR, it was deemed not appropriate to incorporate it in the Western European energy model.

The LWR is the only fission option considered in the evaluation of the potential of fusion power in Western Europe. Annex B, Table B1, shows investment costs of three German Konvoi plants (PWRs), commissioned around 1988, as well as one N4 (PWR, planned but never been built in Belgium). Investment costs range from ECU 1870/kW to ECU 2200/kW [2, 3]. These figures include the first core and interest during construction (IDC), based on a discount rate of 5%. A representative investment cost figure is ECU 2060/kW (Table A.1), almost the same as the investment cost of the EPR[1] presented in [4] (a contribution of FZ Jülich to SE0). Operation and maintenance costs, including several insurance costs, are estimated at ECU 46/kW/year[1] [5, 6].

2.3 Fusion power

Gilli and Kurz give a detailed assessment [7] of the economics of fusion power as a contribution to macro task SE0. As this study became available in an early stage of the SERF programme, the results are used as reference. Other cost estimates are used in the sensitivity analysis. The study is based on analysis of the stage of development and demonstration on the one hand, and the stage of commercialisation on the other hand. Before the commercial stage, investment costs come down rapidly. Most of the cost reduction is realised in the so-called fusion core. The cost of the so-called Balance of Plant (BOP) does not show similar opportunities for cost reduction. After having reached a competitive cost level, learning is related to the production of increasing numbers of (larger) identical fusion power plants rather than to major changes of the technology.

The investment cost of a twin 1500 MW fusion power plant is derived from the corresponding cost of a single 1000 MW fusion power plant, taking into account cost degression with unit size and cost degression with number of units at one site. Because of these two degression factors, the investment cost of a twin 1500 MW fusion power plant is 33% lower than that of a single 1000 MW plant, according to Gilli and Kurz [7].

Annex B, Table B2, presents the investment costs of a twin 1500 MW fusion power plant, which is assumed to be available from 2070 on. In 2070 the specific investment costs are ECU 3210/kWe. In the year 2100 costs have come down to ECU 2980/kWe. Table A.2 shows the investment cost over time, as well as the operation and maintenance costs, including replacement costs of diverter, blanket, and first wall.

[1] In [4] investment costs of the European Pressurized Water Reactor (EPR) are estimated at ECU 1600/kW in ECU's 1990, which is equal to ECU 1900/kW in ECU's 1995.

3. FOSSIL FUEL BASED POWER

3.1 Introduction

Coal is a main fuel for power generation in Western Europe. Natural gas is used for industrial Combined Heat and Power (CHP), district heating (the Netherlands), sometimes for base-load power production and for peak load gas turbines. The model of the Western European energy system includes a number of fossil fuel based power generation options. Section 3.2 addresses coal-fired options, and Section 3.3 addresses oil-fired and gas-fired options.

3.2 Coal-fired power

Annex B, Table B3, presents investment costs of German coal-fired power plants [8, 9]. Contribution [4] of FZ Jülich to SE0 gives similar data. Until recently, coal-fired power plants in Europe were based on steam parameters up to 540 °C and 250 bar. Supercritical live steam conditions of 620 °C and 300 bar, single reheat with 600 °C and 55 bar and very low condenser pressures (0.036 bar) enable efficiencies beyond 45% [4]. The level of investment cost assumed here is ECU 1190/kWe (Table A.3). Investment cost of desulphurisation and low-NO_x burnes are included The net generating efficiency is assumed to increase from 46% in 2000 to 50% in 2030.

Also Integrated Gasification Combined Cycle (IGCC) is considered (Table A.4):
- investment cost ECU 1450/kW in 2000, decreasing to ECU 1290/kW in 2040,
- net generating efficiency increasing from 48% in 2000 to 52% in 2040.

These assumptions are mainly based on the FZ Jülich study [4].

Alternatively, IGCC with CO_2 capture and sequestration could be applied (Table A.5):
- investment cost ECU 1820/kW in 2010, decreasing to ECU 1710/kW in 2040,
- net generating efficiency increasing from 43% in 2010 to 45.5% in 2040.

This technology has to be developed. Parameters have been derived from e.g. [10].

Additionally two very advanced coal-fired options are considered, viz. IGCC combined with SOFC, Solid Oxide Fuel Cells (Table A.6) and the same option in combination with CO_2 separation and sequestration (Table A.7). Investment costs and operation and maintenance costs of these options are quite uncertain. However, their inclusion in the data base gives fossil-fired power sufficient room for improvement, both in efficiency and in CO_2 reduction terms. Table A.8 presents a less advanced option, viz. Fluidised Bed Combustion (FBC) based on hard coal. Atmospheric FBC power plants of some 100-200 MWe are mainly used for industrial CHP and district heating.

At last, we address lignite-fired power plants. Generally, they are based on live steam parameters of 580 °C and 260 bar. Their net efficiency is about 43% (study FZ Jülich [4]). Optimised technology can be improved by integrated lignite drying in a fluidised bed with utilisation of the condensation heat of the water vapour. Annex B, Table B3, shows characteristics of lignite-fired power plants [11, 12, 13, 14, 15] and data from FZ Jülich [4]. Table A.9 presents data on advanced lignite-fired power plants as a function of time.

3.3 Oil- and gas-fired power

Oil fired power options, based on either conventional steam boilers or IGCC, are presented in Tables A.10 and A.11 respectively. Investment costs of IGCCs based on residual oil are somewhat lower than those of IGCCs based on hard coal.

Tables A.12 to A.18 show a range of gas-fired options, notably:

- combined cycle plant (for district heating or power only),
- combined cycle plant combined with SOFC (fuel cells) for district heating,
- gas turbine peaking plant,
- gas turbine plant for industrial CHP (Combined Heat and Power),
- combined cycle plant for industrial CHP,
- gas engine for total energy application,
- Heron gas turbine with SOFC (fuel cells) for total energy application.

These options are mainly based on earlier studies of ECN Policy Studies [16, 17], and on the FZ Jülich study [4].

4. RENEWABLE POWER

4.1 Introduction

Hydro power is a commercial renewable power option. Wind turbines on land and near-shore have become established technologies, whereas offshore wind power is in the stage of demonstration. Commercialisation depends on sufficient cost reduction in the next decades. Solar power is generally based on photovoltaic energy (PV). The model includes several PV options, as well as solar thermal power. At last wave energy, tidal energy, geothermal energy, and waste-to-energy power are considered.

For biomass-fuelled power a range of options is available, which have been described in a recent analysis of the CO_2 reduction potential of biomass technologies for the Netherlands [18]. The availability of biomass in Western Europe has been analysed in [19].

4.2 Hydro power

There are several types of hydro power plants, such as reservoir type and run-of-river plants. We assume most of hydro capacity to be of the medium to high head type (reservoir type plants), and a smaller fraction of the low head type (run-of-river plants). Characteristics of these two types of hydro power, based on [16], are shown in Tables A.19 and A.20. Hydro power plants have load factors ranging from 36% to 50%.

4.3 Wind energy

Data on wind energy - onshore (inland and shore), near-shore, offshore - in Western Europe have been updated since 1997 [16]. Characteristics of these categories of wind power are shown in Tables A.21 to A.24. Offshore is divided in two categories: near-shore (less than 10 km from the shore) and offshore. Investment costs of onshore wind turbines are relatively low. Load factors range from 24% for inland windturbines to 36% for offshore windturbines (Tables A.21 and A.24 respectively). The higher load factor of offshore (and near-shore) wind does not offset the higher investment cost, which are ECU 1515/kW for offshore wind versus ECU 820-840/kW for onshore wind in 2040.

The maximum installed capacity potentials of these categories of wind power in Western Europe are as follows:

- onshore wind, inland locations: 33 GW,
- onshore wind, shore locations: 42 GW,
- near-shore wind (distance to shore less than10 km): 12.5 GW,
- offshore wind (distance to shore 10 km and more): 112.5 GW.

The total maximal installed capacity of wind power in Western Europe in 2100 is thus estimated at 200 GW.

4.4 Solar energy

Photovoltaic power (PV) is an important power generation option (Table A.25 to A.28). Solar thermal power generation is already available, but only applicable in Southern Spain (Tale A.29). Besides, solar thermal power seems to be less promising than PV.
The two types of solar PV considered are:

- average of roofs and land at the latitude of Madrid,
- roofs in three regions, from latitude Amsterdam to latitude Lyon, and latitude Malaga.

The average load factor ranges from 10.6% in Northern Europe (latitude Amsterdam) to 19.4% the latitude of Malaga. These data are mainly derived from an earlier (1997) study of ECN Policy Studies [16]. The maximum installed capacity of the four categories are:

- Northern Europe (central UK, IRL, NL, B, northern Germany, DK): 120 GW_p,
- Central Europe (FR, Southern Germany, CH, AU): 180 GW_p,
- Southern Europe (central Spain and Italy): 125 GW_p,
- Latitude Malaga (most southern Spain, Italy, Greece): 50 GW_p.

The total maximum installed capacity of PV in Western Europe is thus estimated at 475 GW. Besides, the potential of solar thermal power plants in Southern Europe is estimated at 5 GW.

4.5 Remaining renewable power options

A rather novel option is wave power, an option with potential in Portugal and Ireland. A device called Archimedes Wave Swing with a capacity of 8 MW per module makes effective use of the energy in long waves on the Atlantic coast. Demonstration will start within a few years. Investment cost is approx. ECU 1600/kW, the annual load factor is 50%. Its potential in Portugal and Ireland is estimated at 4 GW [20] (Table A.29).

Tidal power is largely proven technology. Tidal power schemes have been proposed for the UK (Severn estuary). Investment costs are approx. ECU 1775/kW, with an average load factor of 23%. The Western European potential is estimated at 10 GW. Table A.30 shows their characteristics, based on studies on tidal power in the UK [21, 22].

At last, Tables A.31 and A.32 contain data on geothermal power [23, 24] and waste-to-energy power plants [25], respectively.

5. OVERVIEW OF POWER GENERATION COSTS

Some representative power generation options are exhibited in three figures, showing their power generation costs. Figure 5.1 shows the options selected, with climbing generation costs for the *year 2070* and a *discount rate of 8%,* and based on the fuel prices of scenario MD (Market Drive) [1]. It comes out that fusion power is more expensive than e.g. offshore wind and solar PV at central European latitude (Lyon). It should be noted, however, that generation costs are not fully comparable, as some options like wind and solar power are intermittent options. However, it is a crude way to rank these options with respect to generation costs.

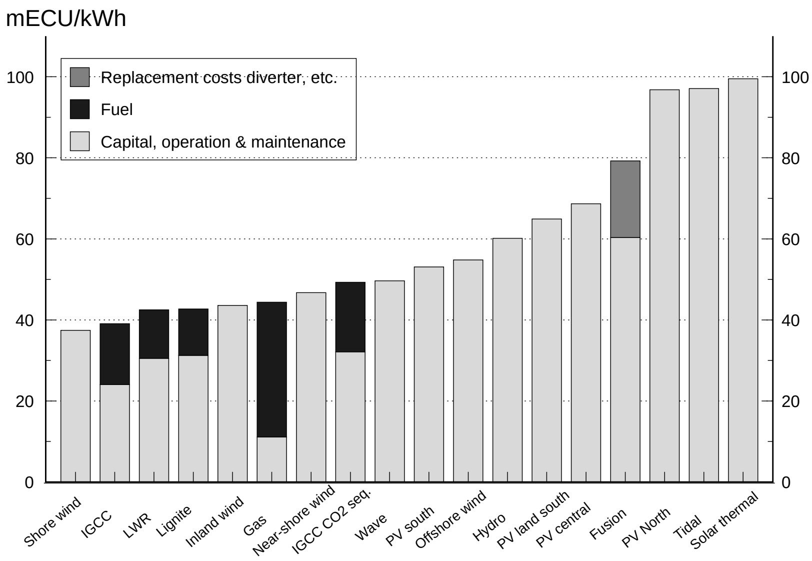

Figure 5.1 *Comparison of generation cost of some representative power generation options of the 21st century, fuel prices of scenario MD, discount rate 8%, year 2070*

Figure 5.2 shows the generation costs for the *year 2100* and a *discount rate of 8%,* also based on the fuel prices of scenario MD. At last, Figure 5.3 presents the same options for the *year 2100* and a *discount rate of 5%,* based on the fuel prices of scenario RP (Rational Perspective). Note that the prices of natural gas in scenario RP are lower than in case of scenario MD. Further, the technology presumed for gas fired power is the combined cycle power plant.

It comes out that the gap between e.g. fusion power and renewable options like offshore wind and PV at central European latitude becomes rather small towards 2100. Taking into account the intermittent nature of wind and solar energy, it is allowed to generalise that fusion power and new renewables like offshore wind and PV at central European latitudes have generation costs which are of the same order of magnitude.

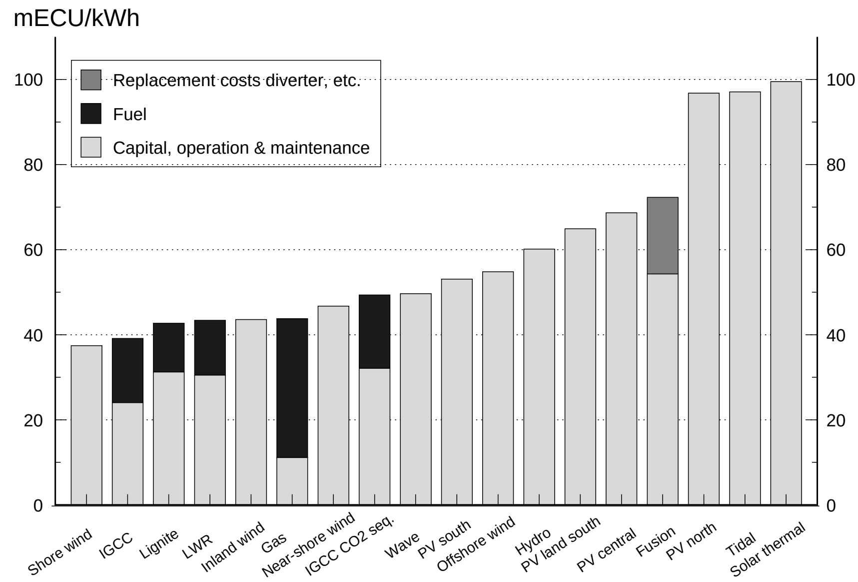

Figure 5.2 *Comparison of generation cost of some representative power generation options of the 21st century, discount rate 8%, year 2100 (scenario MD)*

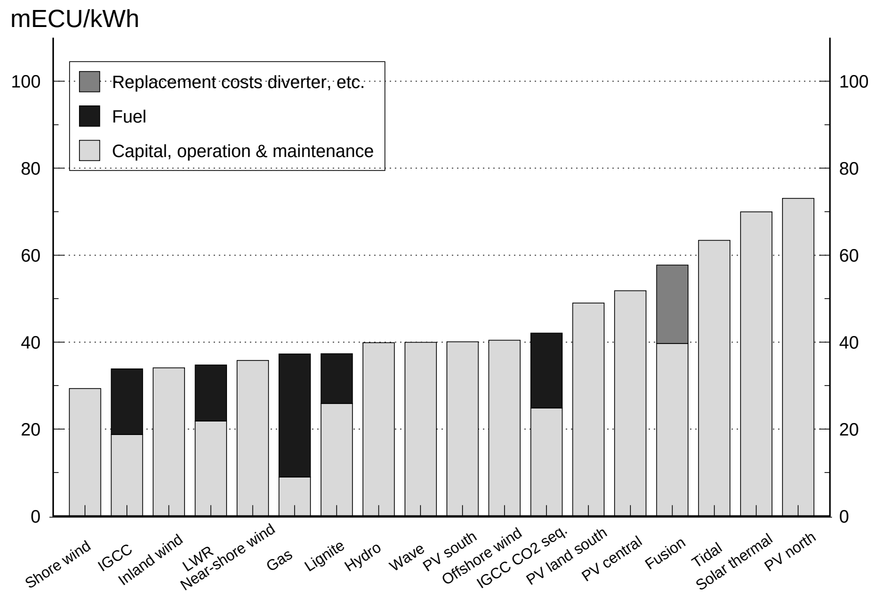

Figure 5.3 *Comparison of generation cost of some representative power generation options of the 21st century, discount rate 5%, year 2100 (scenario MD)*

ANNEX A MARKAL DATA OF POWER GENERATION OPTIONS

The tables of Annex A contain characteristic data of power generation options. Not all power generation options of the MARKAL model (58) are included, but those included (33) are deemed to be key technologies or representative options.

Table A.1 *Technical economic characteristics of Light Water Reactor (LWR)*

LWR (EN0)				1990	2000	2010	2020	2030	2040	2050	2070	2100
	Life	[×10 year]	4									
	Building schedule	[year]	6									
.	Eff	[%]	33.5									
	Load factor	[%]		72.5	75	77.5	80	82.5	85	87.5	87.5	87.5
	Total capital cost (1)	[ECU/kWe]	1700									
	IDC (2)	[ECU/kWe]	268									
	First core (3)	[ECU/kWe]	89									
	Decom fund (4)	[ECU/kWe]	29									
	Invcost (1+2+3+4)	[ECU/kWe]	2086	2085	2085	2085	2085	2085	2085	2085	2085	2085
	O&M cost	[ECU/kWe]	46	46	46	46	46	46	46	46	46	46
	Resid	[GWe]		80.65	80.59	77.96	32.92	6.28	0	0	0	0
	Boundlo	[GWe]		118.4	126.7	124	78.99	14.59	8.3			
Scenario Market Drive	Boundup	[GWe]		118.4	126.7	126.7	126.7	114	114	114	101.3	101.3
	Ibondup	[GWe/10 year]		37.77	8.305	2.63	45.04	51.75				
Scenario Rational Perspective	Boundup	[GWe]		118.4	126.7	126.7	126.7	107.7	107.7	107.7	88.7	88.7
	Ibondup	[GWe/10 year]		37.77	8.305	2.63	45.04	45.41				

Life = economic lifetime IDC = Interest during construction &M = eration and maintenance cost ff = efficiency
Invcost = investment cost Varom = variable operation and maintenance cost ondup = aximum investment in new capacity per period esid = residual capacity

Table A.2 *Technical economic characteristics of Fusion Power*

Fusion power (EN1)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	6.25									
Start	[year]	2030									
Eff	[%]	46.3									
Load factor	[%]						67.5	70	72.5	75	75
Total capital cost (1)	[ECU/kWe]	2576									
IDC (2)	[ECU/kWe]	424									
Invcost (1+2)	[ECU/kWe]	3000				9378	8279		6080	3408	3000
O&M cost	[ECU/kWe]	184				430	377		270	190	184
Boundup	[GWe]						1	2.5	7	60	200
Ibondup	[GWe/10 year]						1	1.5	4.5	31.5	69

Note: Maximum of fusion power in 2070: 58.9 GW, and in 2100: 157.5 GW.

Table A.3 *Technical economic characteristics of Advanced Pulverised Coal Fired Power Plant*

Advanced pulverised fired power plant (EC4)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	3.25									
Start	[year]	2000									
Eff	[%]			46	48	49	50	50	50	50	50
Load factor	[%]	75									
Total capital cost (1)	[ECU/kWe]	1100									
IDC (2)	[ECU/kWe]	91									
Invcost (1+2)	[ECU/kWe]	1191		1190	1190	1190	1190	1190	1190	1190	1190
O&M cost	[ECU/kWe]	37		37	37	37	37	37	37	37	37
Varom	[ECU/GJe]	0.26		0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26

Table A.4 *Technical economic characteristics of Integrated Gasification Combined Cycle (IGCC)*

Integrated gasification combined cycle (EC5)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	3									
Start	[year]	2000									
Eff	[%]			48	49	50	51	52	52	52	52
Load factor	[%]	75									
Total capital cost (1)	[ECU/kWe]	1202									
IDC (2)	[ECU/kWe]	91									
Invcost (1+2)	[ECU/kWe]	1293		1450	1360	1320	1300	1290	1290	1290	1290
O&M cost	[ECU/kWe]	31		31	31	31	31	31	31	31	31
Varom	[ECU/GJe]	0.3		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Table A.5 *Technical economic characteristics of IGCC with Water Gas Shift Conversion and CO_2 Sequestration*

IGCC, water gas shifgt conversion and CO_2 sequestration (EC5+)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	3.5									
Start	[year]	2010									
Eff	[%]				42.88	43.75	44.63	45.5	45.5	45.5	45.5
Load factor	[%]	75									
Total capital cost (1)	[ECU/kWe]	1566									
IDC (2)	[ECU/kWe]	140									
Invcost (1+2)	[ECU/kWe]	1706			1820	1755	1725	1710	1710	1710	1710
O&M cost	[ECU/kWe]	43			44	43	43	43	43	43	43
Varom	[ECU/GJe]	0.38			0.38	0.38	0.38	0.38	0.38	0.38	0.38

Table A.6 *Technical economic characteristics of Integrated Coal Gasification SOFC Power Plant*

Integrated coal gasification SOFC power plant (EC8)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	3									
Start	[year]	2020									
Eff	[%]					53	54.5	56	57.5	57.5	57.5
Load factor	[%]	75									
Total capital cost (1)	[ECU/kWe]	1286									
IDC (2)	[ECU/kWe]	98									
Invcost (1+2)	[ECU/kWe]	1384				1490	1430	1400	1385	1385	1385
O&M cost	[ECU/kWe]	43				47	45	44	43	43	43
Varom	[ECU/GJe]	1.7				1.7	1.7	1.7	1.7	1.7	1.7

Table A.7 *Technical economic characteristics of IG SOFC Power Plant with CO2 Separation and Sequestration*

IG SOFC power plant, CO_2 separation and sequestration (EC8+)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	3.5									
Start	[year]	2030									
Eff	[%]						49.05	50.4	51.75	51.75	51.75
Load factor	[%]	75									
Total capital cost (1)	[ECU/kWe]	1585									
IDC (2)	[ECU/kWe]	141									
Invcost (1+2)	[ECU/kWe]	1726					1785	1745	1725	1725	1725
O&M cost	[ECU/kWe]	53					56	54.5	53	53	53
Varom	[ECU/GJe]	1.8					1.8	1.8	1.8	1.8	1.8

Table A.8 *Technical economic characteristics of Coal Fluidised Bed Combustion Combined Heat and Power Plant*

Coal FBC CHP plant (ECA)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	3									
Start	[year]										
Eff											
Electric		11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Thermal		75	75	75	75	75	75	75	75	75	75
Load factor	[%]	80									
Total capital cost (1)	[ECU/kWe]	2788									
IDC (2)	[ECU/kWe]	212									
Invcost (1+2)	[ECU/kWe]	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
O&M cost	[ECU/kWe]	120	120	120	120	120	120	120	120	120	120

Table A.9 *Technical economic characteristics of Advanced Lignite Fired Power Plant*

Advanced lignite fired power plant (EC6)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	4									
Start	[year]	2000									
Eff	[%]			43	46	47.5	49	49	49	49	49
Load factor	[%]	80									
Total capital cost (1)	[ECU/kWe]	1185									
IDC (2)	[ECU/kWe]	121									
Decomfund (3)	[ECU/kWe]	7									
Invcost (1+2)	[ECU/kWe]	1314		1265	1290	1315	1315	1315	1315	1315	1315
O&M cost	[ECU/kWe]	81		75	78	81	81	81	81	81	81
Varom	[ECU/GJe]	0.60		0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60

Table A.10 *Technical economic characteristics of Advanced Oil Fired Power Plant*

Advanced oil fired power plant (ED1)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	3.5									
Start	[year]	2000									
Eff	[%]	45		45	45	45	45	45	45	45	45
Load factor	[%]	75									
Total capital cost (1)	[ECU/kWe]	721									
IDC (2)	[ECU/kWe]	64									
Invcost (1+2)	[ECU/kWe]	785		785	785	785	785	785	785	785	785
O&M cost	[ECU/kWe]	24		24	24	24	24	24	24	24	24
Varom	[ECU/GJe]	0.26		0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26

Table A.11 *Technical economic characteristics of Oil Fired IGCC*

Oil fired IGCC (ED1)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	2.5									
Building schedule	[year]	3									
Start	[year]	1990									
Eff	[%]		44.5	46	47.5	49	50.5	52	52	52	52
Load factor	[%]	75									
Total capital cost (1)	[ECU/kWe]	1322									
IDC (2)	[ECU/kWe]	100									
Invcost (1+2)	[ECU/kWe]	1423	1850	1610	1500	1450	1425	1425	1425	1425	1425
O&M cost	[ECU/kWe]	29	29	29	29	29	29	29	29	29	29
Varom	[ECU/GJe]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table A.12 *Technical economic characteristics of Gas Fired Combined Cycle Power Plant*

Gas fired combined cycle power plant (EG3)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	2.5									
Building schedule	[year]	2.5									
Start	[year]	2000									
Eff	[%]			56	57	58	59	60	60	60	60
Load factor	[%]	75									
Total capital cost (1)	[ECU/kWe]	508									
IDC (2)	[ECU/kWe]	32									
Invcost (1+2)	[ECU/kWe]	540	670	540	540	540	540	540	540	540	540
O&M cost	[ECU/kWe]	10		10	10	10	10	10	10	10	10
Varom	[ECU/GJe]	0.45		0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45

Table A.13 *Technical economic characteristics of Combined Cycle SOFC Power Plant*

Combined cycle SOFC power plant (EG4)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	2.5									
Building schedule	[year]	2.5									
Start	[year]	2000									
Eff	[%]				64	66	68	70	70	70	70
Load factor	[%]	75									
Total capital cost (1)	[ECU/kWe]	817									
IDC (2)	[ECU/kWe]	51									
Invcost (1+2)	[ECU/kWe]	869			1050	950	905	880	870	870	870
O&M cost	[ECU/kWe]	24			27	26	25	24	24	24	24
Varom	[ECU/GJe]	1.4			1.4	1.4	1.4	1.4	1.4	1.4	1.4

Table A.14 *Technical economic characteristics of Gas Turbine Peaking Plant*

Gas turbine peaking plant (EG1)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	2.5									
Building schedule	[year]	1.5									
Start	[year]										
Eff	[%]		33	34.5	36	37.5	39	39	39	39	39
Load factor	[%]	25									
Total capital cost (1)	[ECU/kWe]	365									
IDC (2)	[ECU/kWe]	14									
Invcost (1+2)	[ECU/kWe]	379	380	380	380	380	380	380	380	380	380
O&M cost	[ECU/kWe]	11	11	11	11	11	11	11	11	11	11
Varom	[ECU/GJe]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Table A.15 *Technical economic characteristics of Gas Turbine Combined Heat and Power Plant*

Gas turbine CHP plant (EGD)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	2.5									
Building schedule	[year]	1.5									
Start	[year]	2000									
Eff											
Electric	[%]			33	34	35	36	37	37	37	37
Thermal	[%]			47	46	45	44	43	43	43	43
Load factor	[%]	80									
Total capital cost (1)	[ECU/kWe]	733									
IDC (2)	[ECU/kWe]	27									
Invcost (1+2)	[ECU/kWe]	760		760	760	760	760	760	760	760	760
O&M cost	[ECU/kWe]	11		11	11	11	11	11	11	11	11
Varom	[ECU/GJe]	0.5		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Table A.16 *Technical economic characteristics of Combined Cycle Combined Heat and Power Plant*

Combined cycle CHP plant (EGE)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	2.5									
Building schedule	[year]	2.5									
Start	[year]	2000									
Eff											
Electric	[%]			43	44	45	46	47	47	47	47
Thermal	[%]			29	28	27	26	25	25	25	25
Load factor	[%]	80									
Total capital cost (1)	[ECU/kWe]	558									
IDC (2)	[ECU/kWe]	35									
Invcost (1+2)	[ECU/kWe]	593		590	590	590	590	590	590	590	590
O&M cost	[ECU/kWe]	12.5		12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Varom	[ECU/GJe]	0.55		0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Table A.17 *Technical economic characteristics of Gas Engine Total Energy*

Gas engine total energy (EGF)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	1.5									
Building schedule	[year]	0.25									
Start	[year]	2000									
Eff											
Electric	[%]			36	37	38	39	39	39	39	39
Thermal	[%]			52.5	52	51.5	51	51	51	51	51
Load factor	[%]	0.5									
Invcost (1+2)	[ECU/kWe]	950		950	950	950	950	950	950	950	950
O&M cost	[ECU/kWe]	24		24	24	24	24	24	24	24	24
Varom	[ECU/GJe]	0.2		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table A.18 *Technical economic characteristics of Heron Turbine SOFC (Total Energy)*

Heron turbine SOFC (EGG)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	2.5									
Building schedule	[year]	0.4									
Start	[year]	2000									
Eff											
Electric	[%]			55	25.7	59	60	60	60	60	60
Thermal	[%]			25	22.5	21	20	20	20	20	20
Load factor	[%]	50									
Invcost (1+2)	[ECU/kWe]	1010		1325	1135	1050	1010	1010	1010	1010	1010
O&M cost	[ECU/kWe]	34		38	36	34	34	34	34	34	34
Varom	[ECU/GJe]	1.4		1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4

Table A.19 *Technical economic characteristics of Medium and High Head Hydro Power*

Medium and high head hydro power (EH0)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	7.5									
Building schedule	[year]	7									
Start	[year]										
Load factor	[%]	36									
Total capital cost (1)	[ECU/kWe]	1442									
IDC (2)	[ECU/kWe]	269									
Invcost (1+2)	[ECU/kWe]	1711	1710	1710	1710	1710	1710	1710	1710	1710	1710
O&M cost	[ECU/kWe]	38	38	38	38	38	38	38	38	38	38

Table A.20 *Technical economic characteristics of Low Head Hydro Power*

Low head hydro power (EH1)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	7.5									
Building schedule	[year]	5									
Start	[year]										
Load factor	[%]	50									
Total capital cost (1)	[ECU/kWe]	2404									
IDC (2)	[ECU/kWe]	312									
Invcost (1+2)	[ECU/kWe]	2716	2715	2715	2715	2715	2715	2715	2715	2715	2715
O&M cost	[ECU/kWe]	38	38	38	38	38	38	38	38	38	38

Table A.21 *Technical economic characteristics of Onshore Wind Energy, Inland Location*

Onshore wind energy inland location (EW5)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	0.25									
Start	[year]										
Load factor	[%]	24	24	24	24	24	24	24	24	24	24
Invcost	[ECU/kWe]	841	1150	1000	865	840	840	840	840	840	840
O&M costs	[ECU/kWe]	17	23	20	17	17	17	17	17	17	17
Resid	[GWe]		0.022	0.011	0	0	0	0	0	0	0
Boundlo	[GWe]		0.065	2	3	3	3	3	3	3	3
Boundup	[GWe]		0.066	2.15	5.5	10.3	15.1	20	24.9	33	33
Ibondup	[GWe/10 year]		0.044	2.1	3.3	4.9	6.9	8.2	9.8	11.5	11.5

Table A.22 *Technical economic characteristics of Onshore Wind Energy, Shore Location*

Onshore wind energy shore location (EW6)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	0.25									
Start	[year]										
Load factor	[%]	27.4	27.4	27.4	27.4	27.4	27.4	27.4	27.4	27.4	27.4
Invcost	[ECU/kWe]	817	1130	985	840	820	820	820	820	820	820
O&M costs	[ECU/kWe]	17	23	20	17	17	17	17	17	17	17
Resid	[GWe]		0.125	0.065	0	0	0	0	0	0	0
Boundlo	[GWe]		0.374	4	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Boundup	[GWe]		0.375	4.3	10.5	18.3	25.8	31.7	36.1	42	42
Ibondup	[GWe/10 year]		0.35	3.9	6.2	8.2	11.4	12.1	12.6	14.7	14.7

Table A.23 *Technical economic characteristics of Near-Shore Wind Energy*

Near shore wind energy (EW6)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	4									
Building schedule	[year]	1									
Start	[year]	2000									
Load factor	[%]	33.8		33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
Total capital cost (1)	[ECU/kWe]	1171									
IDC (2)	[ECU/kWe]	29									
Invcost (1+2)	[ECU/kWe]	1200		1930	1510	1340	1260	1220	1200	1200	1200
O&M cost	[ECU/kWe]	36		58	45	40	38	37	36	36	36
Boundlo	[GWe]			0.2	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Boundup	[GWe]			0.215	2.5	5.75	8.45	10	11.3	12.5	12.5
Ibondup	[GWe/10 year]			0.215	2.3	3.2	3.2	3.2	3.2	3.2	3.2

Table A.24 *Technical economic characteristics of Offshore Wind Energy*

Offschore wind energy (EW7)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	4									
Building schedule	[year]	4									
Start	[year]	2010									
Load factor	[%]	36.5			36.5	36.5	36.5	36.5	36.5	36.5	36.5
Total capital cost(1)	[ECU/kWe]	1373									
IDC (2)	[ECU/kWe]	141									
Invcost (1+2)	[ECU/kWe]	1513			1800	1630	1550	1515	1515	1515	1515
O&M cost	[ECU/kWe]	41			51	45	43	41	41	41	41
Boundup	[GWe]				3.25	14.7	34.7	58.5	84.2	112.5	112.5
Ibondup	[GWe/10 year]				3.25	11.45	20	23.6	29.15	30.6	30.6

Table A.25 *Technical economic characteristics of PV on Roofs, Northern Europe*

PV on roofs northern Europe (ES1) Latitude Amsterdam			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	0.25									
Start	[year]	2000									
Annual load factor	[%]	10.64		10.64	10.64	10.64	10.64	10.64	10.64	10.64	10.64
	[hours/year]	932		932	932	932	932	932	932	932	932
Winter day	[%]	7.14		7.14	7.14	7.14	7.14	7.14	7.14	7.14	7.14
Winter night	[%]										
Summer day	[%]	24.56		24.56	24.56	24.56	24.56	24.56	24.56	24.56	24.56
Summer night	[%]										
Intermediate day	[%]	16.12		16.12	16.12	16.12	16.12	16.12	16.12	16.12	16.12
Intermediate night	[%]										
Invcost	[ECU/kWe]	930		5000	1980	1525	1070	930	930	930	930
O&M cost	[ECU/kWe]	7.6		20.5	14.8	11.45	8.1	7.6	7.6	7.6	7.6
Boundlo	[GWe]			0.05							
Boundup	[GWe]			1	2.5	10	20	40	60	100	120
Ibondup	[GWe/10 year]			1	2.5	7.5	12.5	20	30	35	40

Table A.26 *Technical economic characteristics of PV on Roofs, Central Europe*

PV on roofs, Central Europe (ES3) Latitude Lyon			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	0.25									
Start	[year]	2000									
Annual load factor	[%]	15		15	15	15	15	15	15	15	15
	[hours/year]	1314		1314	1314	1314	1314	1314	1314	1314	1314
Winter day	[%]	10.07		10.07	10.07	10.07	10.07	10.07	10.07	10.07	10.07
Winter night	[%]										
Summer day	[%]	34.59		34.59	34.59	34.59	34.59	34.59	34.59	34.59	34.59
Summer night	[%]										
Intermediate day	[%]	22.73		22.73	22.73	22.73	22.73	22.73	22.73	22.73	22.73
Intermediate night	[%]										
Invcost	[ECU/kWe]	930		5000	1980	1525	1070	930	930	930	930
O&M cost	[ECU/kWe]	7.6		20.5	14.8	11.45	8.1	7.6	7.6	7.6	7.6
Boundlo	[GWe]			0.15	0.15	0.15					
Boundup	[GWe]			1	5	15	37.5	70	100	140	180
Ibondup	[GWe/10 year]			1	5	10	25	37.5	40	50	60

Table A.27 *Technical economic characteristics of PV on Roofs, Southern Spain*

PV on roofs, southern spain (ES2) Latitude Malaga			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	0.25									
Start	[year]	2000									
Annual load factor	[%]	19.4		19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4
	[hours/year]	1700		1700	1700	1700	1700	1700	1700	1700	1700
Winter day	[%]	15.6		15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
Winter night	[%]										
Summer day	[%]	42.7		42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7
Summer night	[%]										
Intermediate day	[%]	29.2		29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2
Intermediate night	[%]										
Invcost	[ECU/kWe]	930		5000	1980	1525	1070	930	930	930	930
O&M cost	[ECU/kWe]	7.6		20.5	14.8	11.45	8.1	7.6	7.6	7.6	7.6
Boundlo	[GWe]			0.15	0.15	0.15					
Boundup	[GWe]			1	7.5	12.5	27.5	42.5	50	50	50
Ibondup	[GWe/10 year]			2	7.5	10	17.5	22.5	22.5	22.5	22.5

Table A.28 *Technical economic characteristics of PV on Roofs and Barren Land, Central Spain*

PV on roofs and barren land central spain (ES4) Latitude Madrid			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	0.25									
Start	[year]	2000									
Annual load factor	[%]	18.26		18.25	18.25	18.25	18.25	18.25	18.25	18.25	18.25
	[hours/year]	1600		1600	1600	1600	1600	1600	1600	1600	1600
Winter day	[%]	14.65		14.65	14.65	14.65	14.65	14.65	14.65	14.65	14.65
Winter night	[%]										
Summer day	[%]	40.1		40.1	40.1	40.1	40.1	40.1	40.1	40.1	40.1
Summer night	[%]										
Intermediate day	[%]	27.42		27.42	27.42	27.42	27.42	27.42	27.42	27.42	27.42
Intermediate night	[%]										
Invcost	[ECU/kWe]	962		5750	2750	1980	1525	1070	1070	1070	1070
O&M cost	[ECU/kWe]	7.6		22	16	12.5	9.2	8.7	8.7	8.7	8.7
Boundlo	[GWe]			0.05	0.05	0.05					
Boundup	[GWe]			1	2.5	7.5	22.5	45	67.5	115	125
Ibondup	[GWe/10 year]			2	2.5	5	15	25	27.5	50	50

Table A.29 *Technical economic characteristics of Solar Thermal Power Plant*

Solar thermal power plant (ES7) Latitude Southern Spain			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	4									
Building schedule	[year]	3									
Start	[year]	1990									
Annual load factor	[%]	25	25	25	25	25	25	25	25	25	25
	[hours/year]	2190									
Winter day	[%]	15	15	15	15	15	15	15	15	15	15
Winter night	[%]	0	0	0	0	0	0	0	0	0	0
Summer day	[%]	75	75	75	75	75	75	75	75	75	75
Summer night	[%]	0	0	0	0	0	0	0	0	0	0
Intermediate day	[%]	30	30	30	30	30	30	30	30	30	30
Intermediate night	[%]	0	0	0	0	0	0	0	0	0	0
Capital cost (1)	[ECU/kWe]	2045									
IDC (2)	[ECU/kWe]	155									
Invcost (1+2)	[ECU/kWe]	2200	2700	2400	2260	2200	2200	2200	2200	2200	2200
O&M cost	[ECU/kWe]	25	30	29	28	27	26	25	25	25	25
Boundlo	[GWe]		0.05	0.05	0.05	0.05	0				
Boundup	[GWe]		0.055	0.25	0.5	1	2	3	4	5	5
Ibondup	[GWe/10 year]		0.055	0.2	0.5	1	1.25	1.25	1.25	1.25	1.25

Table A.30 *Technical economic characteristics of Archimedes Wave Swing*

Archimed wave swing (EH3) Wave power, Portugal and Ireland			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	2									
Start	[year]	2000									
Annual load factor	[%]	50		50	50	50	50	50	50	50	50
	[hours/year]	4380									
Winter day	[%]	60		60	60	60	60	60	60	60	60
Winter night	[%]	60		60	60	60	60	60	60	60	60
Summer day	[%]	40		40	40	40	40	40	40	40	40
Summer night	[%]	40		40	40	40	40	40	40	40	40
Intermediate day	[%]	50		50	50	50	50	50	50	50	50
Intermediate night	[%]	50		50	50	50	50	50	50	50	50
Capital cost (1)	[ECU/kWe]	1538									
IDC (2)	[ECU/kWe]	77									
Invcost (1+2)	[ECU/kWe]	1615		1800	1700	1650	1630	1615	1615	1615	1615
O&M cost	[ECU/kWe]	72		80	77	74	72	70	70	70	70
Boundlo	[GWe]			0.008	0.008	0.008	0				
Boundup	[GWe]			0.04	0.5	1.2	2.4	3.6	4	4	4
Ibondup	[GWe/10 year]			0.04	0.46	0.7	1.25	1.3	1.35	1.35	1.35

Table A.31 *Technical economic characteristics of Tidal Energy*

Tidal energy (EH4)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	6									
Building schedule	[year]	8.5									
Start	[year]	2010									
Annual factor	[%]	23			23	23	23	23	23	23	23
	[hours/year]	2015									
Winter day	[%]	24.5			24.5	24.5	24.5	24.5	24.5	24.5	24.5
Winter night	[%]	20			20	20	20	20	20	20	20
Summer day	[%]	24.5			24.5	24.5	24.5	24.5	24.5	24.5	24.5
Summer night	[%]	20			20	20	20	20	20	20	20
Intermediate day	[%]	24.5			24.5	24.5	24.5	24.5	24.5	24.5	24.5
Intermediate night	[%]	20			20	20	20	20	20	20	20
Capital cost (1)	[ECU/kWe]	1442									
IDC (2)	[ECU/kWe]	332									
Invcost (1+2)	[ECU/kWe]	1775			1775	1775	1775	1775	1775	1775	1775
O&M Cost	[ECU/kWe]	34			34	34	34	34	34	34	34
Boundlo	[GWe]		0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Boundup	[GWe]		0.245	0.245	1.04	9.68	9.68	9.68	9.68	9.68	9.68
Ibondup	[GWe/10 year]		0	0	0.8	8.64	8.64	8.64	8.64	8.64	8.64

Table A.32 *Technical economic characteristics of Geothermal Power*

Geothermal power (ET1)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	4									
Start	[year]										
Eff	[%]	15	15	15	15	15	15	15	15	15	15
Annual load factor	[%]	70									
Capital cost (1)	[ECU/kWe]	1000									
IDC (2)	[ECU/kWe]	103									
Invcost (1+2)	[ECU/kWe]	1103	1100	1100	1100	1100	1100	1100	1100	1100	1100
O&M cost	[ECU/kWe]	26	26	26	26	26	26	26	26	26	26
Boundlo	[GWe]		0.54	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Boundup	[GWe]		0.55	0.7	1	1.6	1.6	1.6	1.6	1.6	1.6
Ibondup	[GWe/10 year]			0.15	0.3	0.6	0.6	0.6	0.6	0.6	0.6

Table A.33 *Technical economic characteristics of Waste-To-Energy Power*

Wast-to-energy power (EI1)			1990	2000	2010	2020	2030	2040	2050	2070	2100
Life	[×10 year]	3									
Building schedule	[year]	3									
Start	[year]										
Eff	[%]		22.5	24	26	28	29	30	30	30	30
Annual load factor	[%]	75									
Capital cost (1)	[ECU/kWe]	8150									
IDC (2)	[ECU/kWe]	619									
Invcost (1+2)	[ECU/kWe]	8769	11000	9750	9180	8900	8770	8770	8770	8770	8770
O&M cost	[ECU/kWe]	67	85	77	72	69	67	67	67	67	67
Boundlo	[GWe]		0.565	1.5	2.1	2.55	3.05	3.55	3.55	3.55	3.55
Boundup	[GWe]		0.575	1.9	2.75	4	5.25	6.25	6.25	6.25	6.25

ANNEX B BACKGROUND DATA ON IMPORTANT POWER GENERATION OPTIONS

Annex B gives background information on a few important power generation options, notably fission power, fusion power, lignite-fired power, and coal-fired power.

Table B.1 *Basic data with respect to investment cost of Fission Power*

	Type of LWR			PWR	PWR	PWR	PWR	Ref. PWR		Notes
	Type of PWR			Konvoi	Konvoi	Konvoi	N4			
	Reactor			KKI-2	KKE	GKN-2				
	Commissioned	JS		1988	1988	1989	(1992)			
	Rated power (net)	RP	[MWe]	1365	1290	1269	1390		1330	Konvoi reactors have been uprated
	Construction schedule	CS	[year]	5.6	5.8	6.2	6.23	6	6	
	Inv. cost incl. of IDC	INV	[million DM88]	4448	4273	5080				(**) J.G. Kim, 1991, page 50
I	Construction cost	CC	[DM88/kWe]	2586	2608	3100				1/(1.086)**(CS/2)*(**)/RP*1000
II	exclusive of first core		[ECU95/kWe]	1546	1559	1825		1643	1700	((1+INFL)**7)*DM_NLG/ECU_NLG*CC
III	Construction cost		[Bfr92/kWe]				65149			
IV	inclusive of first core		[ECU95/kWe]				1782			((1+INFL)**3)*BFR_NLG/ECU_NLG*CC
V	Interest during constr.	IDC	[DM88/kWe]	379	396	506				((1+DR)**(CS/2) - 1)*CC
VI	Discount rate 5%	Disc. Rate 5%	[Bfr92/kWe]				10693			
VII			[ECU95/kWe]	226	237	298	292	263	268	
VIII			[DM88/kWe]	622	652	835				
IX	Discount rate 8%	Disc. Rate 8%	[Bfr92/kWe]				17650			
XI			[DM88/kWe]	791	830	1066				
XII	Discount rate 10%	Disc. Rate 10%	[Bfr92/kWe]				22520			
XIII			[ECU95/kWe]	473	496	637	616	555	563	
	First core	FC	[million DM88]	225	191	175				J.G. Kim, 1991, page 50
XIV			[DM88/kWe]	165	148	138				FC/RP×1000
XV			[ECU95/kWe]	99	88	81		89	89	
XV=I+V+XIV	Investment cost	Disc. Rate 5%	[DM88/kWe]	3130	3152	3744				SUM(CC+IDC+FC)

DM95/NLG95 1.1202   BFR95/NLG95 0.0544   Average deflation capital goods 0.015

Continuation of Table B.1				KKI-2	KKE	GKN-2	N4	Ref. PWR		Notes
XVI			[Bfr92/kWe]				83360			SUM(CC+IDC)+GC_SIM
XVII=II+VII+XV			[ECU95/kWe]	1871	1884	2205	2280	2060	2057	N4 would have somewhat lower cost than ECU 2280/kWe
XV=I+VIII+XIV		Disc. rate 8%	[DM88/kWe]	3373	3408	4073				(2074), excl. of connection to grid and simulator cost
XVI			[Bfr92/kWe]				90317			
XVII=II+X+XV			[ECU95/kWe]	2016	2037	2406	2470	2232	2231	N4 would have cost ECU 2264/kWe, excl. of connection
XVIII=I+XI+XIV		Disc. rate 10%	[DM88/kWe]	3542	3586	4303				to grid and simulator cost
XIX			[Bfr92/kWe]				95187			
XX(=II+XIII+XV)			[ECU95/kWe]	2117	2143	2543	2603	2352	2352	N4 would have cost ECU 2398/kWe, excl. of connection to grid and simulator cost
	Decommissioning cost	Disc. rate 5%	[ECU95/kWe]						29	Based on publication (G. Frederick et al) on N4 cost 1/((1+DR)**LIFE)*DEC_FAC*CC
DEC_FAC =	0.12	Disc. rate 8%	[ECU95/kWe]						9	
LIFE	40	Disc. rate 10%	[ECU95/kWe]						5	

Table B.2 *Basic data with respect to investment cost of Fusion Power*

	Type of reactor	Tokamak		ITER								Note
	Denomination				DEMO RS (Fe1.0)	Commercial stage		DEMO RS (Fe1.0)	Commercial Single reactor	Commercial Twin reactor	Commercial Twin reactor	
	Commissioned (year)	JS		2011	2020	2050	2070	2020	2050	2070	2100	
	Structural material			Fe	Fe	V	V	Fe	V	V	V	
	Coolant			water	water	helium	helium	water	helium	helium	helium	
	Total thermal power		[MWth]		3239	2431	3239	3239	2431	3646,5	3646,5	
	Fusion power	RPG	[MWth]		2879	2160	3110	2879	2160	3240	3240	
	Rated power (net)	RP	[MWe]		1000	1000	1500	1000	1000	1500	1500	
	Net efficiency		[%]		34,7	46,3	46,3	34,7	46,3	46,3	46,3	RP/RPG*100
	Construction schedule	CS	[year]	8	7	6,25	6,25	7	6,25	6,25	6,25	
I	Fusion core	FC	[million ECU95]	3871				5314	2932	1296	1202	
	Balance of plant	BOP						2592	2288	1383	1374	
VI=IV+V	Total construction cost	TCC	[ECU/kWe]					7906	5220	2926	2576	TCC=FC+BOP
	Interest during constr.	IDC										
VII		Disc. rate 5%	[ECU/kWe]					1472	860	482	424	
VIII		Disc. rate 8%	[ECU/kWe]					2444	1419	796	700	
IX		Disc. rate 10%	[ECU/kWe]					3130	1811	1015	894	
X=VI+VII	Investment cost	Disc. rate 5%	[ECU/kWe]					9378	6080	3408	3000	
XI=VI+VIII		Disc. rate 8%	[ECU/kWe]					10350	6639	3722	3276	
XII=VI+IX		Disc. rate 10%	[ECU/kWe]					11036	7031	3941	3470	

Fusion power(EN1) $93/ECU93 0,8571 Average deflation capital goods 0.015

References P.V. Gilli, R. Kurz: Fusion power as an additional vector in the IIASA-WEC world scenarios (1998)
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Table B.3 *Basic data with respect to investment cost of Pulverised Coal Fired Power Plant*

	Type of power plant Site			Coal fired Supercritical Rostock	Coal fired Supercritical Elsdorf			Coal fired Supercritical/ultrasupercritical		
	Commissioned (year)	JS		1994	2004	2000	2010	2020	2030	2100
	Rated power (net)	RP	[MWe]	500	500					
	Construction schedule	CS	[year]	3,25	3,25	3,25	3,25	3,25	3,25	3,25
	Net efficiency			42,5	46	46	48	49	50	50
I	Inv. cost incl. of IDC	INV	[million DM]	1300	1200					
II			[DM95/kWe]	2639	2330					
III			[ECU95/kWe]	1422	1256					
IV	Construction cost	CC	[DM95/kWe]	2308	2071					
V	excl. of IDC		[ECU95/kWe]	1244	1116	1100	1100	1100	1100	1100
VI	IDC	IDC	[DM95/kWe]	190	171					
VII		Disc. rate 5%	[ECU95/kWe]	103	92	91	91	91	91	91
VIII		Disc. rate 8%	[DM95/kWe]	307	276					
IX			[ECU95/kWe]	166	149	147	147	147	147	147
X		Disc. rate 10%	[DM95/kWe]	387	347					
XI			[ECU95/kWe]	208	187	184	184	184	184	184
XII=IV+VI	Investment cost	Disc. rate 5%	[DM95/kWe]	2498	2242					
XIII=V+VII			[ECU95/kWe]	1347	1209	1191	1191	1191	1191	1191
XIV=IV+VIII		Disc. rate 8%	[DM95/kWe]	2615	2347					
XV=V+IX			[ECU95/kWe]	1410	1265	1247	1247	1247	1247	1247
XVI=IV+X		Disc. rate 10%	[DM95/kWe]	2695	2418					
XVII=V+XI			[ECU95/kWe]	1452	1303	1284	1284	1284	1284	1284

EC4 Reference coal fired power plant development 0.015 DM/95/ECU95 0.539

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P. Ruhland: Modernes 500-Megawatt-Kraftwerk Rostock eingeweiht. Energiewirtsch. Tagesfragen, November 1994, 726-727.
Energiewirtsch. Tagesfragen, March 1997, 183-184.

Table B.4 *Basic data with respect to investment cost of Lignite-Fired Power Plant*

	Type of power plant Site			Lignite fired 2×450 MWe Schkopau	Lignite fired 400 MWe Altbach/Dieizisau	Lignite fired 2×906 MWe Lippendorf	BoA 950 MWe Niederaussen	BoA	BoA-plus	BoA-plus	BoA-plus	BoA-plus
	Commissioned (year)	JS		1996	1997	1998	2002	2000	2010	2020	2030	2100
	Rated power (net)	RP	[MWe]	900	400	1812	950					
	Construction schedule	CS	[year]	4	4	4	4	4	4	4	4	4
	Net efficiency			40	40	41	43	43	46	47,5	49	49
I	Inv. cost incl. of IDC	INV	[million DM]	2500	1300	5000	2300					
II			[DM95/kWe]	2737	3155	2639	2315					
III			[ECU95/kWe]	1475	1700	1422	1248					
IV	Construction cost	CC	[DM95/kWe]	2390	2755	2305	2022					
V	excl. of IDC		[ECU95/kWe]	1288	1485	1242	1090	1142	1163	1185	1185	1185
VI	IDC	IDC	[DM95/kWe]	245	282	236	207					
VII		Disc. rate 5%	[ECU95/kWe]	132	152	127	112	117	119	121	121	121
VIII		Disc. rate 8%	[DM95/kWe]	398	458	384	337					
IX			[ECU95/kWe]	214	247	207	181	190	194	197	197	197
X		Disc. rate 10%	[DM95/kWe]	502	579	484	425					
XI			[ECU95/kWe]	271	312	261	229	240	244	249	249	249
XII=IV+VI	Investment cost	Disc. rate 5%	[DM95/kWe]	2635	3038	2541	2230					
XIII=V+VII			[ECU95/kWe]	1420	1637	1370	1202	1259	1283	1306	1306	1306
XIV=IV+VIII		Disc. rate 8%	[DM95/kWe]	2788	3214	2688	2359					
XV=V+IX			[ECU95/kWe]	1503	1732	1449	1271	1332	1357	1382	1382	1382
XVI=IV+X		Disc. rate 10%	[DM95/kWe]	2892	3334	2789	2447					
XVII=V+XI			[ECU95/kWe]	1559	1797	1503	1319	1382	1408	1434	1434	1434
	Decommissioning cost	Disc. rate 5%	[ECU95/kWe]					7	7	7	7	7
		Disc. rate 8%	[ECU95/kWe]					3	3	3	3	3
		Disc. rate 10%	[ECU95/kWe]					2	2	2	2	2

EC6 DM95/ECU95 0.539 Average inflation capital goods 0.015 Reference lignite fired power plant development

References
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Schkopau powers recovery with local lignite. Modern Power Systems, September 1996, Supplement, 21-25
W. Hlubek et al: Entwicklungslinien der Braunkohle-Kraftwerkstechnik. Energiewirtsch. Tagesfragen, September 1997, 512-519
BWK, July/August 1996, 21-22.

ANNEX C LIST OF ENERGY CARRIERS/ MATERIALS TECHNOLOGIES AND DEMAND CATEGORIES IN MARKAL EUROPE 2.0

This annex presents an overview of the main constituents of the MARKAL-EUROPE 2.0 energy system model databases. As such, it provides an indication of the level of detail and comprehensiveness of the energy system modelled.

Subsequently, the following is listed (set symbol between brackets):

- 113 energy carriers and materials, representing the flows in the energy system network (set ENT in MARKAL),
- 536 technologies, subdivided into:
  - 46 conversion technologies producing electricity (set CON); the data for most of these technologies are presented in Annex A,
  - 154 conversion technologies producing other than electricity output (processes, set PRC),
  - 335 end-use technologies serving the useful energy demand (set DMD),
  - 51 useful energy demand categories (set DM).

All energy carriers/materials (total: 113)

CSV	Energy saving	FEQ	FOSSIL EQUALIVANT
BCE	Lignite for electricity generation	OLS	Oil shale
BCT	Total lignite (brown coal)	PCI	Petroleum coke for industry
BIT	Bitumina	PCK	Petroleum coke
CCO	Coking coal	PPH	Petroleum products for households
CCS	Coking coal for industry	SMW	Solid municipal waste
COA	Coal for agricultural sector	STW	Straw
COC	Coal for commercial sector	VRE	Vacuum residue
COE	Coal for electricity generation	WDH	Wood for households
COF	Coal for fuel conversion sector	WOD	Wood
COH	Coal for households	WOS	Wood for steel industry
COI	Coal for industry	HTS	High temperature steam
COK	Cokes	LTS	Low temperature steam
COR	Coke iron production	TEH	Total energy heat in residential sector
COS	Coal iron production	TET	Total energy heat
COT	Coal total primary	URA	uranium for power plant
COX	Fuel for IGCC power plant	GEO	Geothermal heat
COY	Coal for IG SOFC plant	SOL	Solar irradiation
DSL	Diesel	WAT	Hydro energy
DST	Diesel for transport sector	WDC	Wood chips
FOA	Residual fuel oil for agriculture	WIN	Wind energy
FOC	Residual fuel oil for commercial sector	ETH	Ethanol
FOE	Residual fuel oil for electricity	ETT	Ethanol for transport sector
FOI	Residual fuel oil for industry	GSS	Residual gas from steel industry
FOL	Residual fuel oil	HYL	Liquid hydrogen
FOT	Residual fuel oil for transport sector	MCB	Bricks
GAA	Gas for agricultural sector	MCC	Cement clinker
GAC	Gas for commercial sector	MET	Methanol
GAE	Gas for electricity generation	MIC	Chlorine
GAF	Gas for fuel conversion sector	MIF	Ammonia
GAH	Gas for households	MMA	Aluminium
GAI	Gas for industry	MMD	DRI quality steel
GAS	Natural gas	MMF	Direct Reduced Iron
GAX	Natural gas for STAG power plant	MMH	High quality hot rolled steel
GOA	Gas oil for agricultural sector	MMI	Iron
GOC	Gas oil for commercial sector	MML	Low quality hot rolled steel
GOI	Gas oil for industry	MMM	Medium quality hot rolled steel
GOL	Gas oil	MMS	High quality steel sheet
GSA	Gasoline for agricultural sector	MNP	Paper
GSI	Gasoline for industry	MNU	Pulp
GSL	Gasoline	MPE	Olefins
GST	Gasoline for transport sector	MPO	Polyolefins
HOE	Heavy oil products (PCK and BIT) for el	MPS	Styrene
HYD	Hydrogen	MTT	Methanol for transport sector
HYT	Hydrogen for transport sector	OLB	Biomass crude
KRI	Kerosene for industry	ORE	Iron ore
KRS	Kerosene	OXY	Oxygen
KRT	Kerosene for transport sector	PEL	Pellets
LPG	Liquified Petroleum Gas	RLC	Cold rolling steel dummy
LPI	LPG for industry	RLH	Hot rolling steel dummy
LPT	LPG for transport sector	SIN	Sinter
NAI	Naphtha for industry	WCC	Blast furnace slag
NAP	Naphtha	WMA	Waste aluminium
OLH	Heavy crude	WMF	Waste steel
STS	High temperature steam from steel ind.	WNP	Waste paper
TEC	Total energy heat in commercial sector	WPO	Waste polyolefins

Electricty production (total: 46)

	Fossil (24)
Coal	
EC2	Existing pulverised coal fired p.p.
EC3	Existing lignite fired power plant
EC4	New pulverised coal fired power plant
EC5	Integrated coal gasification p.p.
EC6	New lignite fired power plant
EC7	Integr. lignite power plant
EC8	Integrated Coal Gasification SOFC plant
ECA	Coal FBC CHP plant
Oil	
ED0	Existing oil fired power plant
ED1	New oil fired power plant
ED2	Oil gasification combined cycle p.p.
Gas	
EG0	Existing gas fired power plant
EG1	Gas turbine peaking plant
EG2	Existing STAG power plant
EG3	New STAG power plant
EG4	Combined cycle SOFC power plant
EGA	Existing gas turbine CHP plant
EGB	Existing STAG CHP plant
EGC	Exist. gas eng. gen. set for H,C and A
EGD	New gas turbine CHP plant
EGE	New STAG CHP plant
EGF	New gas engine gen. set for H, C and A
EGG	HERON SOFC total energy for H, C and A
Waste	
EI1	Waste to energy plant (incinerator)
	Nuclear (2)
EN0	LWR power plant (fission)
EN1	Fusion power plant
	Renewable (19)
Biomass	
BE1	Wood gasification:small industrial cog.
BE2	Biomass gasifier:STAG power plant
BE3	Biomass gasifier:ISTIG+reheat
Hydro, wave, tidal	
EH0	Medium and high head hydro
EH1	Low head hydro
EH3	Archimedes Wave Swing
EH4	TIDAL ENERGY
Solar	
ES1	Solar PV in Northern Europe
ES2	Solar PV roofs southern ESP, IT, GR
ES3	Solar PV in Central Europe
ES4	Solar PV roofs/barren land cent. ESP, IT
ES5	Solar PV: import from North Africa

Wind	
EW4	Large onshore wind turbine - inland
EW5	Large onshore wind turbine - shore
EW6	Off-shore wind turbine - near shore
EW7	Off-shore wind turbine - off shore
	Storage (1)
EH2	Hydro pumped storage

ES6	SNAP energy tower in desert North. Afr.
ES7	Solar thermal power plant in south. ESP
Geothermal	
ET1	geoThermal energy

Process Technologies (total: 154)

BB1	Biomass:briqu. plant
BC1	Biomass: wood chipping
BF1	Biomass:methanol from straw
BP1	Biomass:diesel from rapeseed Middle
BP2	Biomass:ethanol from wheat Middle
BP3	Biomass:ethanol from sugarbeet Middle
BP4	Biomass:straw from miscanthus Middle
BP5	Biomass:wood short rot. forests Middle
BPA	Biomass:diesel from rapeseed South
BPB	Biomass:ethanol from wheat South
BPC	Biomass:ethanol from sugarbeet South
BPD	Biomass:straw from miscanthus South
BPE	Biomass:wood short rot. forests South
GL1	Gas to liquids, mainly diesel
GL2	Gas to liquids, mainly kerosine
IAA	Aluminium production Hall-Heroult
IAB	Aluminium production inert anodes
IAR	Aluminium production recycling
IBA	Brick production tunnel kiln
IBB	Brick production roller kiln
ICA	Chlorine prod. membrane electr.
ICB	Chlorine prod. adv. membrane electr.
IGA	Iron prod. BF max coal inj.
IGB	Iron prod. COREX
IGC	Iron prod. CCF
IGD	Coke oven
IGE	Sponge iron prod. DRI
IGF	Sponge iron prod. DRI -CO2
IGG	Dummy cokes for iron production
IGH	Dummy cokes for iron production -CO2
IGI	Dummy coal for iron production
IGJ	Dummy coal for iron production -CO2
IGK	Dummy residual gas from steel industry
IGL	Dummy residual steam from steel industr
IGM	Dummy residual steam from steel ind. HP
IGN	Steel prod. hot rolling advanced
IGO	Steel prod. cold rolling
IGP	Steel prod. hot rolling
IGQ	Steel prod. BOF+additional scrap
IGR	Steel prod. scrap:EAF
IGS	Steel prod. BOF
IGT	Steel prod. DRI:EAF
IGU	Sinter production
IGV	Pellet production
IGW	Dummy DRI steel to high quality
IPA	Polyolefin prod. polymerization
IPB	Polyolefin prod. recycling
IRA	Ammonia prod. conventional
IRB	Ammonia prod. advanced
IRC	Ammonia prod. conventional -CO2
IRD	Ammonia prod. advanced -CO2
ITA	Styrene production Monsanto:Lummus Cres
ITB	Styrene production catalytic membrane
IUA	Cement clinker dry process
IUB	Cement clinker wet process
IUC	Cement clinker from blast furnace slag
IVA	Paper production conventional
IVB	Paper production impulse:cond. belt
IVE	Mechanical pulp production
IVF	Chemical pulp production
IVG	Recycling pulp production
OCR	Catalytic reformer
OFC	Fluid catalytic cracker
OFX	Flexi coker
OH1	Refinery heavy crude
OHC	Hydrocracker
OHF	Hydrocracker for fuel oil
OHY	Hycon
OL1	Refinery light crude
OVS	Visbreaker
SAT	Ethanol to transport sector
SBA	Dummy ethanol to gasoline
SBB	Dummy methanol to gasoline
SBE	Lignite to electricity generation
SBL	Dummy biocrude to light crude
SCA	Coal to agricultural sector
SCC	Coal to commercial sector
SCE	Coal to electricity generation
SCF	Coal to fuel conversion sector
SCH	Coal to households
SCI	Coal to industry
SCM	Coal to methanol
SCS	Coking coal to industry
SDT	Diesel to transport sector
SEH	Electrolysis (electricity to hydrogen)
SFA	Residual fuel oil to agricultural secto
SFC	Residual fuel oil to commercial sector
SFE	Residual fuel oil to electricity sector
SFH	Residual fuel oil to households
SFI	Residual fuel oil to industry
SFT	Residual fuel oil to transport sector

steel
IGX Dummy mixing DRI:scrap based steel
IGY Dummy high to medium quality steel
IGZ Dummy medium to low quality steel
IHA Charcoal production for steel industry
IHB Dummy wood to coal:iron production
IHC Dummy wood to coal:iron production - CO2
IHD Waste plastic for steel industry (extr.
INA Petroch. Naphtha cracker
INB Petroch. Gas oil cracker
INC Petroch. Ethane cracker
IND Petroch. Oxydative coupling
INE Petroch. MTO
INF Petroch. LPG cracker
SHZ Hydrogen to commercial
SIH Dummy oIl shale to Heavy crude
SKT Kerosene to transport sector
SLI LPG to industry
SLT LPG to transport sector
SMT Methanol to transport sector
SNI Naphtha to industry
SOA Gas oil to agricultural sector
SOC Gas oil to commercial sector
SOH Gas oil to households
SOI Gas oil to industry
SOT Gas oil to transport sector
SPH Petroleum products to households
SPI Petroleum coke to industry
SRB Dummy bitumina to oil for electricity
SRF Dummy petrocoke to oil for electricity
SRM Dummy gasoline to diesel
SRN Dummy diesel to kerosene
SRO Dummy kerosene to naphtha
SRP Dummy naphtha to gasoil
SRQ Dummy gasoil to residual fuel oil
SRR Dummy residual fuel oil to bitumen
SSA Gasoline to agricultural sector
SSH Gasoline to households
SSI Gasoline to industry
SST Gasoline to transport sector
STH Dummy high to low temperature steam
STL Dummy low temperature steam production
SWH Wood to households
SZ1 Coal for IGCC plant (dummy)
SZ2 Coal for IGCC plant with CO2 removal
SZ3 Natural gas for STAG plant (dummy)
SZ4 Natural gas STAG plant with CO2 removal
SZ5 Nat.gas to hydrogen with CO2 remova
SZ6 Coal to hydrogen with CO2 removal
SZ7 Coal for IG SOFC plant (dummy)
SZ8 Coal for IG SOFC plant with CO2 remova
SZU Oxygen production
SGA Gas to agricultural sector
SGC Gas to commercial sector
SGE Gas to electricity generation
SGF Gas to fuel conversion sector
SGH Gas to households
SGI Gas to industry
SGM Natural gas to methanol
SHC Total energy heat to commerce
SHH Total energy heat to households
SHL Hydrogen (transport) to liquid hydrogen
SHT Hydrogen to transport sector
SHY Hydrogen to households

Demand (end-use) technologies (total: 335)

AD1	Dummy agricultural diesel demand
AE1	Dummy agricultural electricity demand
AG1	Dummy natural gas to agricultural secto
C00	Gas boiler (N. Europe, comm)
C01	Condensing gas boiler (N. Europe, comm)
C02	Cond.boil.low-e glass (N. Europe, comm)
C03	Cond.boil+low-e+heat recov.(N.Europe)
C06	Oil boiler (North Europe comm. heat)
C07	Oil boil+low-e (North Europe)
C08	Oil.boil+low-e+heat recov.(North Europe
C0A	Coal boiler (North Europe, comm. heat)
C0B	Coal boil+low-e (N.Europe)
C0C	Coal.boil+low-e+heat recov.(N.Europe)
C0E	Electric heatpump (North Europe)
C0F	El.heatpump+low-e glass (North Europe)
C0G	Electric resistance:boiler(North Europe
C0H	El.resist+low-e glass (North Europe)
C0I	El.resist+low-e+heat rec.(North Europe)
C0K	District heat(North Europe, comm.heat)
C0L	District heat+low emit.glass (N.Europe)
C0M	Dist.heat+l.em.gl.+heat rec.(N.Europe)
C0P	TE heat(North Europe)
C0Q	TE heat+low e.glass (N. Europe)
C0R	TE heat+low e+heat rec.(N.Europe)
C10	Gas boiler (M.Euro, small office heat)
C11	Cond.gas boiler (M.Euro, small office)
C12	Cond.boil.low-e glass (M.Eur,small off)
C13	Cond.boil+low-e+heat recov.(M.Eur,sm.of
C16	Oil boiler (M.Europe, small building)
C17	Oil boil+low-e (M.Europe, small build.)
C18	Oil.boil+low-e+heat recov.(M.Eur,sm.of)
C1A	Coal boiler (M.Europe, small building)
C1B	Coal boil+low-e (M.Europe, small build.
C1C	Coal.boil+low-e+heat recov.(M.Eur,sm.of
C1E	Electric heatpump (M.Euro, small office
C1F	El.heatpump+low-e glass (M.Euro,
C2Q	TE heat+low e. (M.Euro, lg.off.)
C2R	TE heat+low e+heat rec.(M.Euro, lg.off.
C30	Gas boiler (South Europe, comm.heat)
C31	Condensing gas boiler (S Europe, comm)
C32	Cond.boil.low-e glass (S. Europe, comm)
C33	Cond.boil+low-e+heat recov.(S.Europe)
C36	Oil boiler (South Europe comm. heat)
C37	Oil boil+low-e (South Europe)
C38	Oil.boil+low-e+heat recov.(South Europe
C3A	Coal boiler (South Europe, comm. heat)
C3B	Coal boil+low-e (S.Europe)
C3C	Coal.boil+low-e+heat recov.(S.Europe)
C3E	Electric heatpump (South Europe)
C3F	El.heatpump+low-e glass (South Europe)
C3G	Electric resistance:boiler(South Europe
C3H	El.resist+low-e glass (South Europe)
C3I	El.resist+low-e+heat rec.(South Europe)
CES	Other commercial electric appliances
I1A	Gas boiler:LTH:large industry
I1B	Fuel oil boiler:LTH:large industry
I1C	Coal boiler:LTH:large industry
I1D	Hydrogen boiler:LTH:large industry
I1E	Electric heatpump:LTH:large industry
I1F	Heat exchanger:LTH:large industry
I2A	Gas burner:HTH:large industry
I2B	Fuel oil burner:HTH:large industry
I2C	Coal burner:HTH:large industry
I2D	Hydrogen burner:HTH:large industry
I2E	Electric heating:HTH:large industry
I2F	LPG burner:HTH:large industry
I3A	Gas boiler:LTH:small industry
I3B	Gas oil boiler:LTH:small industry
I3C	Coal boiler:LTH:small industry
I3D	Hydrogen boiler:LTH:small industry
I3E	Abs. heatpump:LTH:small industry
I3F	Compr. heatpump:LTH:small industry

	sm.off		
C1K	District heat(M.Euro, small office heat	I3G	Electric heatpump:LTH:small industry
C1L	District heat+low emit.glass (M.Euro,SO	I3H	Heat exchanger:LTH:small industry
C1M	Dist.heat+l.em.gl.+heat rec.(M.Euro,SO)	I4A	Gas boiler:HTH:small industry
C1P	TE heat(M.Euro, small office heat)	I4B	Gas oil boiler:HTH:small industry
C1Q	TE heat+low e.glass (M.Euro, sm office)	I4T	Straw boiler:HTH:small industry
C1R	TE heat+low e+heat rec.(M.Euro, sm.off.	I4W	Wood boiler:HTH:small industry
C20	Gas boiler (M.Euro, large office heat)	I5A	El. appl.&light:ELE:large industry
C21	Cond.gas boiler (M.Euro, large office)	I5M	Electric drive:ELE:large industry
C22	Cond.boil.low-e glass (M.Eur,large off)	I5N	Adv. electric drive:ELE:large industry
C23	Cond.boil+low-e+heat recov.(M.Eur,lg.of	I6A	El. appl.&light:ELE:small industry
C26	Oil boiler (M.Europe, large building)	I6M	Electric drive:ELE:small industry
C27	Oil boil+low-e (M.Europe, large build.)	I6N	Adv. electric drive:ELE:small industry
C28	Oil.boil+low-e+heat recov.(M.Eur,lg.of)	IA0	Aluminium prod. dummy
C29	Coal boiler (M.Europe, large building)	IB0	Brick prod. dummy
C2B	Coal boil+low-e (M.Europe, large build.	IC0	Chlorine prod. Dummy
C2C	Coal.boil+low-e+heat recov.(M.Eur,lg.of	IG0	Steel prod. Dummy
C2G	Electric heatpump (M.Euro, large office	IP0	Olefin prod. Dummy
C2I	El.heatpump+low-e glass (M.Euro, lg.off	IR0	Ammonia prod. Dummy
C2K	District heat(M.Euro, large office heat	IS0	Olefine demand excl. polyolefins
C2L	District heat+low emit.glass (M.Euro,LO	IT0	Styrene prod. dummy
C2M	Dist.heat+l.em.gl.+heat rec.(M.Euro,LO)	IU0	Cement clinker prod. dummy

C2M			
C2P	Total energy heat (M.Euro, large office	R4L	Coal stove
IV0	Paper:board prod. dummy	R4M	Wood stove
N1A	Dummy lubricants + bitumen	R5A	District heat exchanger
R1A	District heat exchanger	R5B	District heat+floor insul.+heat recov.
R1B	District heat+floor insul.+heat recov.	R5C	District heat + maximum insulation
R1C	Gas boiler	R5D	Conventional gas boiler
R1D	Condensing gas boiler	R5E	Condensing gas boiler
R1E	R1D + floor insulation	R5F	R5E + floor insulation
R1F	R1E + PU foam + heat recovery	R5G	R5F + heat recovery
R1G	R1F + coated glass	R5H	R5G + coated glass
R1H	R1F + coated and gasfilled glass	R5I	R5G + coated and gasfilled glass
R1I	R1F +3-double coated and gasfilled glas	R5J	R5G +3-double coated and gasfilled glas
R1J	Total energy heat	R5K	Electric heatpump: heat + water
R1K	R1J + floor insulation + heat recovery	R5L	R5K + floor insulation
R1L	R1J + maximum insulation	R5M	R5L + coated glass
R1M	Petroleum products	R5N	R5L + coated and gasfilled glass
R1N	Electric resistance	R5O	R5K + triple glass + impreg. wall insul
R1O	Coal stove	R5P	Total energy heat
R1P	Wood stove	R5Q	R5P + floor insulation + heat recovery

R1X	Electric heatpump North/SFD
R2A	District heat exchanger
R2B	R2A + coated glass
R2C	R2B + heat recovery
R2D	District heat + maximum insulation
R2E	Gas boiler
R2F	Condensing gas boiler
R2G	R2F + coated glass
R2H	R2G + heat recovery
R2I	R2F + maximum insulation
R2J	Petroleum products
R2K	Electric resistance
R2L	Coal stove
R2M	Wood stove
R3A	District heat exchanger
R3B	District heat+floor insul.+heat recov.
R3C	Gas boiler
R3D	Condensing gas boiler
R3E	R3D + floor insulation
R3F	R3E + PU foam + heat recovery
R3G	R3F + coated glass
R3H	R3F + coated and gasfilled glass
R3I	R3F +3-double coated and gasfilled glas
R3J	Total energy heat
R3K	R3J + floor insulation + heat recovery
R3L	R3J + maximum insulation
R3M	Petroleum products
R3N	Electric resistance
R3O	Coal stove
R3P	Wood stove
R3X	Electric heatpump Middle/SFD-existing
R4A	District heat exchanger
R4B	R4A + coated glass
R4C	R4B + heat recovery
R4D	District heat + maximum insulation
R4E	Gas boiler
R4F	Condensing gas boiler
R4G	R4F + coated glass
R4H	R4G + heat recovery
R4I	R4F + maximum insulation
R5R	R5P + maximum insulation
R5S	Petroleum products
R5T	Electric resistance
R5U	Coal stove
R5V	Wood stove
R6A	District heat exchanger
R6B	District heat+floor insul.+heat recov.
R6C	Gas boiler
R6D	Condensing gas boiler
R6E	R6D + floor insulation
R6F	R6E + PU foam + heat recovery
R6G	R6F + coated glass
R6H	R6F + coated and gasfilled glass
R6I	R6F +3-double coated and gasfilled glas
R6J	Total energy heat
R6K	R6J + floor insulation + heat recovery
R6L	R6J + maximum insulation
R6M	Petroleum products
R6N	Electric resistance
R6O	Coal stove
R6P	Wood stove
R6X	Electric heatpump South/SFD
R7A	District heat exchanger
R7B	R7A + coated glass
R7C	R7B + heat recovery
R7D	District heat + maximum insulation
R7E	Gas boiler
R7F	Condensing gas boiler
R7G	R7F + coated glass
R7H	R7G + heat recovery
R7I	R7F + maximum insulation
R7J	Petroleum products
R7K	Electric resistance
R7L	Coal stove
R7M	Wood stove
RA1	Gas boiler water heater
RA2	Combi boiler water heater
RA3	Electric water heater
RA4	Electric heatpump boiler

R4J	Petroleum products
R4K	Electric resistance
RA6	Coal water heater
RA7	Wood water heater
RA8	Solar boiler: electric heatpump backup
RA9	Solar boiler: gas backup
RB1	Gas boiler water heater
RB2	Combi boiler water heater
RB3	Electric water heater
RB4	Electric heatpump boiler
RB5	Petroleum products water heater
RB6	Coal water heater
RB7	Wood water heater
RB8	Solar boiler: el.heatp.backup: ex.house
RB9	Solar boiler: gas backup: existing hous
RA5	Petroleum products water heater
T05	Fuel Cell car with MF and RB
T06	Methanol car with MF and IIC
T07	Ethanol car with MF and IIC
T08	Electric car mid term with MF and RB
T09	Electric car long term with MF and RB
T0A	Ethanol car with MF and partly IIC
T0D	Diesel car standard
T0E	Electric car short term with MF and RB
T0F	Fuel Cell car with MF
T0G	Gasoline car standard
T0M	Methanol car with MF and partly IIC
T11	Diesel van with IIC and MF
T12	Diesel van with IIC, MF and CVT
T13	Gasoline van with IIC and MF

RBA	Solar boiler: el.heatp.backup: new hous
RBB	Solar boiler: gas backup: new house
RC1	Gas boiler water heater
RC2	Combi boiler water heater
RC3	Electric water heater
RC4	Electric heatpump boiler
RC5	Petroleum products water heater
RC6	Coal water heater
RC7	Wood water heater
RC8	Solar boiler: electric heatpump backup
RC9	Solar boiler: gas backup
RD1	Conventional dishwasher
RD2	Dishwasher (enzymatic detergent)
RD3	Dishwasher (enzym.: ASD: optical sensor
RES	Other existing electric appliances
RF1	Gas cooker
RF2	Electric cooker
RF3	Infrared jet impingement cooker
RF4	Petroleum product cooker
RF5	Coal cooker
RF6	Wood cooker
RL1	Incandescent lamp residential
RL2	Halogen lamp residential
RL3	Fluorescent lamp residential
RLA	PL:SL lamp (>350 hours:year)
RLB	PL:SL lamp (300-350 hours:year)
RLC	PL:SL lamp (200-300 hours:year)
RNS	Other new electric appliances
RR1	Old type refrigerator
RR2	Standard refrigerator (3 cm insulation)
RR3	Better insulated absorption refrigerato
RR4	Improved absorption refrigerator
RR5	Stirling refrigerator (krypton panels)
RR6	Stirling refrigerator (soft vac. panels
RT1	Tumble drier (conventional)
RT2	Tumble drier (improved)
RT3	Heat pump drier (improved)
RT4	Tumble drier (improved: high speed spin
RT5	Heat pump drier (impr.: high speed spin
RW1	Conventional washing machine
RW2	Washing machine (ASD: optical sensor)
T01	Gasoline car with MF and partly IIC
T02	Gasoline car with MF and IIC
T14	Gasoline van with IIC, MF and CVT
T15	Fuel Cell van with MF and RB
T16	Electric van mid term with MF and RB
T17	Electric van long term with MF and RB
T18	Hybrid van with MF, RB and CVT
T1D	Diesel van standard
T1E	Electric van short term with MF and RB
T1F	Fuel Cell van with MF
T1G	Gasoline van
T1H	Hybrid van with MF and RB
T21	Diesel truck with IIC
T22	Diesel truck with IIC and MF
T23	Fuel Cell Truck with MF and RB
T2D	Diesel truck standard
T2F	Fuel Cell Truck with MF
T2M	Methanol Truck with MF and IIC
T31	Diesel bus with MF and IIC
T32	Diesel bus with MF, IIC and CVT
T33	Electric bus long term with MF and RB
T3D	Diesel bus standard
T3E	Electric bus mid term with MF and RB
T3F	Fuel Cell bus with MF and RB
T4D	Diesel rail transport
T4E	Electric rail transport
T5D	Diesel inland ships
T5F	Hydrogen inland ships
T6H	Hydrogen aircraft
T6K	Kerosene aircraft
T71	Dummy bunker demand
T04	Diesel car with MF and IIC
T03	Diesel car with MF and partly IIC

Demand categories (total: 51)

AD	Agricultural diesel demand
AE	Agricultural electricity demand
AG	Natural gas to agricultural sector
C0	North Eur. service sect. space heat
C1	Middle Eur. service sect. small buildin

C2	Middle Eur. service sect. large buildin
C3	South Eur. service sect. space heat
CE	Commercial other electricity demand
I1	LTH large industry
I2	HTH large industry
I3	LTH small industry
I4	HTH small industry
I5	ELE large industry
I6	ELE small industry
IA	Aluminium
IB	Bricks
IC	Chlorine
IG	Steel
IP	Polyolefine
IR	Ammonia
IS	Olefine
IT	Styrene
IU	Cement clinker
IV	Paper
N1	Non Energy Use: Lubricants+Bitumen
R1	Space heating:SFD - North Europe
R2	Space heating:MFD - North Europe
R3	Space heating:SFD - Middle Europe
R4	Space heating:MFD - Middle Europe
R5	Space heating:NEW - Middle Europe
R6	Space heating:SFD - South Europe
R7	Space heating:MFD - South Europe
RA	Water heating - North Europe
RB	Water heating - Middle Europe
RC	Water heating - South Europe
RD	Dishwashers
RE	Other existing electric appliances
RF	Food preparation
RL	Lighting
RN	Other new electric appliances
RR	Refrigerators and freezers
RT	Tumble driers
RW	Washing machines
T0	Passenger car
T1	Van
T2	Truck
T3	Bus
T4	Rail Transport
T5	Water Transport Inland
T6	Air Transport
T7	Bunkers

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