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Combined Heat and Power (CHP) Plant Statistics in the EU, 2000

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- CHP electricity generation in the EU in the year 2000 totalled 248.7 TWh, which was 9.6% of total gross electricity generation.
- More than half of the CHP electricity, 145.3 TWh, was produced in industrial plants whilst public supply plants recorded CHP electricity generation of 103.5 TWh.
- The chemical industry (39.4 TWh), the pulp and paper industry (34.0 TWh) and refineries (22.9 TWh) were the largest industrial CHP electricity generators. Two-thirds of the CHP electricity in industry was generated in these three sectors.
- Germany was the largest CHP electricity producer with 60.8 TWh, but Denmark had the largest share of CHP generation in total gross generation, 52.6%.
- CHP heat generation in the EU in the year 2000 was 2155 PJ. About 21% of the CHP heat in the EU was produced in Germany.
- The principal fuel consumed in cogeneration was natural gas, which took 47.0% of the total fuel combustion in CHP plants. The share of renewable fuels was 11.6%.

CHP electricity generation and capacity by Member State

CHP electricity generation in the EU in the year 2000 was 248.7 TWh, corresponding to 9.6% of total electricity generation and 18.2% of conventional thermal electricity generation.

Germany was by far the largest CHP electricity producer in the EU with above 60 TWh in the year 2000. The Netherlands was the second largest generator with 33.7 TWh. Finland, the UK, Italy and Spain are also major CHP generators, each of them producing more than 20 TWh in 2000.

The share of CHP generation in total electricity generation was largest in Denmark, 52.6%. Shares of CHP electricity were also high in the Netherlands and Finland in 2000, at 37.6% and 36.4% respectively. In the other Member States the CHP electricity was less than 20% of total generation.

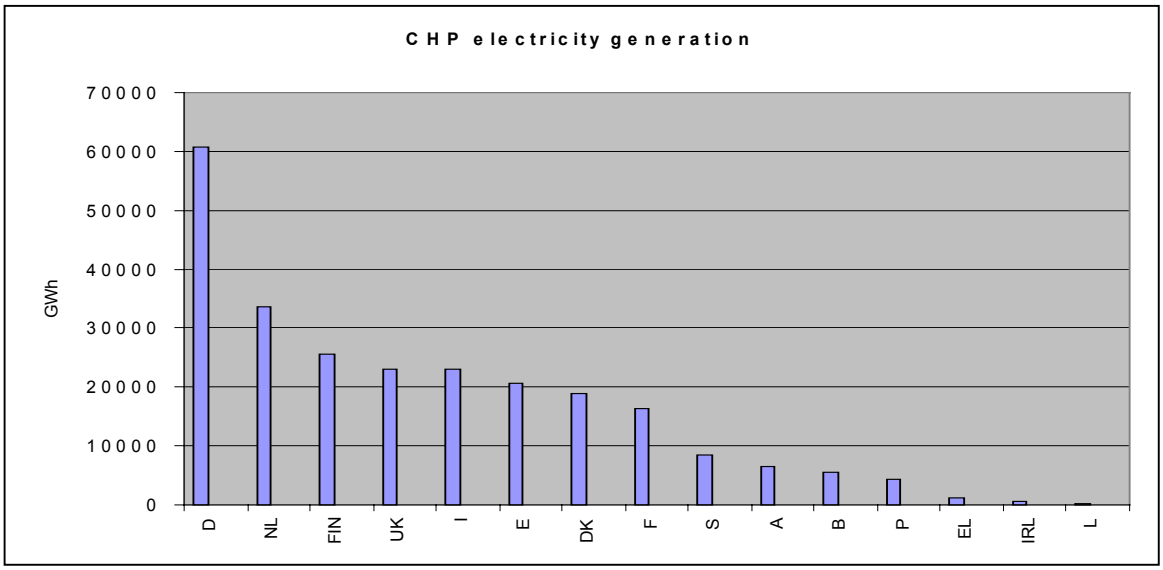
The share of CHP generation in conventional thermal electricity generation was largest in Sweden (93.0%), followed by Finland (77.8%), Luxembourg (72.7%) and Denmark (59.7%).

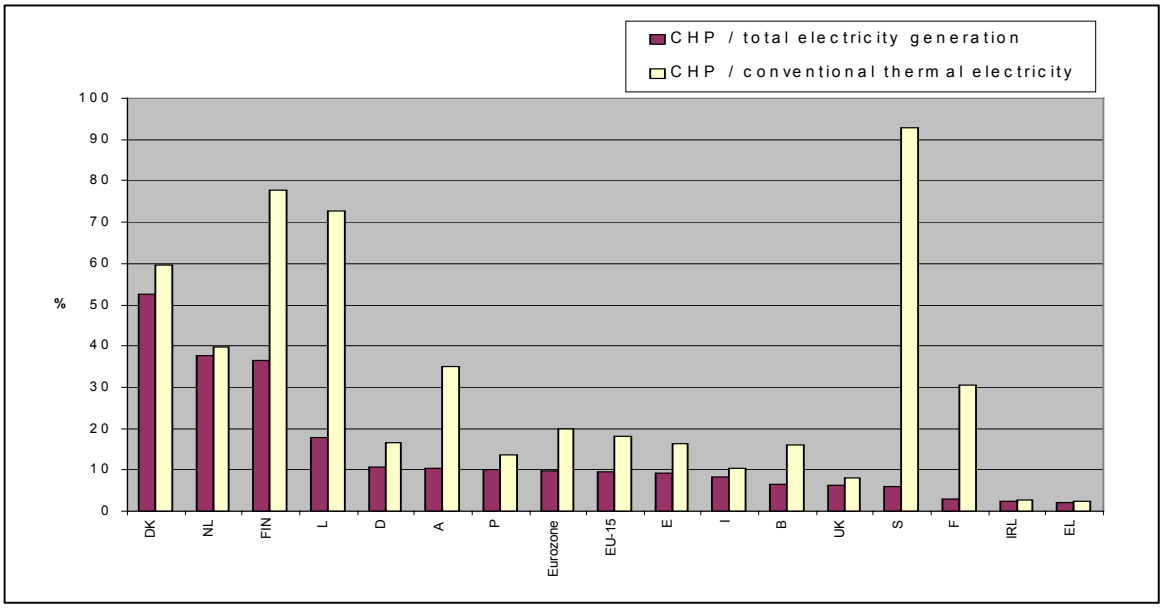
CHP electrical capacity in the EU was 75.5 GW in the year 2000. Germany recorded 18.7 GW, Italy 12.0 GW and the Netherlands 9.1 GW.

CHP Electricity generation, GWh	EU-15	Eurozone	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
Combined cycle	76213	61984	108	2134	10537	-	6441	-	-	8734	142	26805	1590	-	7627	115	11980
Steam : backpressure turbine	74531	61795	1462	2556	28661	473	2691	5711	79	5717	-	1000	2478	1342	12655	8373	1335
Steam : condensing turbine	30105	16387	88	8963	2477	-	644	1875	-	3546	-	743	2092	1039	3884	-	4755
Gas turbine with heat recovery	33400	28420	3393	1506	7972	664	5803	5413	385	3958	-	-	26	204	1266	17	2793
Internal combustion engine	29479	23437	395	3812	6186	-	5127	3282	112	1075	66	5104	222	1790	78	40	2190
Others	5008	5008	-	-	5003	-	-	-	-	-	-	5	-	-	-	-	-
Total CHP electricity generation	**248737**	**197030**	**5445**	**18971**	**60836**	**1137**	**20706**	**16280**	**576**	**23030**	**208**	**33657**	**6408**	**4375**	**25510**	**8546**	**23053**
of which																	
Public supply	103459	81457	4460	16245	34778	147	-	6680	-	955	-	15250	2608	1892	14834	4512	1097
Autoproducers	145279	115574	985	2725	26058	990	20706	9600	576	22075	208	18407	3800	2483	10675	4034	21957
- of total electricity generation, %	10	10	6	53	11	2	9	3	2	8	18	38	10	10	36	6	6
- of conventional thermal generation, %	18	20	16	60	17	2	16	31	3	10	73	40	35	14	78	93	8

CHP Electrical capacity, MW	EU-15	Eurozone	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
Combined cycle	19467	16937	76	517	2425	-	823	-	-	6273	23	5361	532	-	1424	79	1934
Steam : backpressure turbine	22643	17687	528	811	8967	600	662	1715	37	1993	-	337	543	301	2604	3193	352
Steam : condensing turbine	17116	10607	99	3289	2467	-	124	480	-	2427	-	2032	1721	210	1047	-	3220
Gas turbine with heat recovery	8751	7804	599	310	3259	106	940	1607	55	879	-	-	15	73	378	25	506
Internal combustion engine	7535	6094	210	957	1629	-	908	1058	26	422	22	1362	68	339	49	36	448
Others	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**75514**	**59129**	**1512**	**5885**	**18747**	**706**	**3457**	**4861**	**118**	**11994**	**45**	**9092**	**2879**	**923**	**5502**	**3333**	**6460**

Table 1: CHP electricity generation and capacity in EU Member states in the year 2000

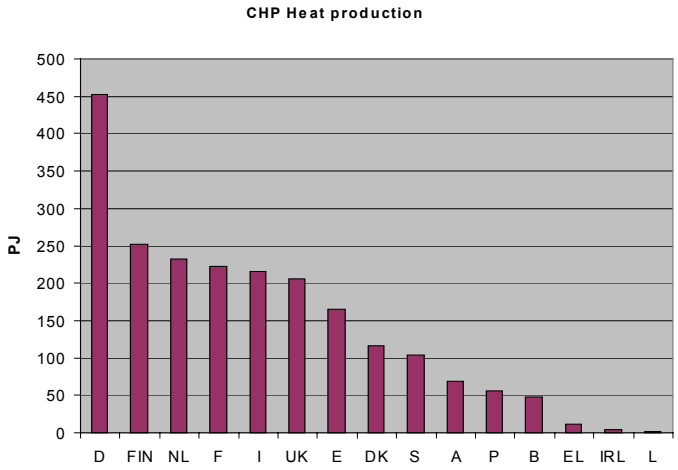




CHP heat generation and capacity by Member State

CHP heat generation in the EU in the year 2000 was 2155 PJ. Germany was by far the largest CHP heat producer with 452 PJ. Finland (251 PJ), the Netherlands (233 PJ), France (223 PJ), Italy (216 PJ) and the UK (206 PJ) also recorded high CHP heat generation figures in 2000.

CHP heat capacity in 2000 was greatest in Germany (40.8 GW) followed by Italy (27.8 GW) and France (17.8 GW).



CHP Heat production, TJ	EU-15	Eurozone	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
Combined cycle	424 831	333 534	911	11391	45 140	-	37 557	-	-	39 485	1082	156 563	9 962	-	31442	1548	89 749
Steam : backpressure turbine	1022 462	878 696	27 012	32 990	253 213	7 852	46 618	150 757	1710	88 896	-	31170	38 592	33 044	182 545	101943	26 120
Steam : condensing turbine	292 870	240 240	1258	43 275	25 474	-	3 897	26 633	-	52 786	-	17 595	19 116	18 865	31340	-	52 630
Gas turbine with heat recovery	224 572	192 240	15 902	9 600	54 144	3 708	46 951	31701	2 381	28 209	-	-	252	924	5 885	392	24 523
Internal combustion engine	150 546	137 653	1929	19 237	34 254	-	29 973	13 537	445	6 195	336	27 307	1291	2 876	273	152	12 741
Others	39 633	39 633	-	-	39 600	-	-	-	-	-	-	33	-	-	-	-	-
Total CHP Heat production	**2 154 914**	**1 821 996**	**47 013**	**116 494**	**451 825**	**11 560**	**164 996**	**222 628**	**4 537**	**215 571**	**1 418**	**232 668**	**69 214**	**55 709**	**251 484**	**104 035**	**205 763**
of which																	
Public supply	695 300	552 040	26 679	88 914	274 741	1174	-	62 783	-	14 490	-	49 548	23 723	10 019	90 057	45 952	7 219
Autoproducers	1459 616	1 165 025	20 334	27 580	177 090	10 386	164 996	159 844	4 537	201081	1418	183 117	45 491	45 690	161427	58 083	198 543

CHP Heat capacity, MW	EU-15	Eurozone	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
Combined cycle	30 650	25 852	157	638	2 886	-	2 326	-	-	10 709	89	7 360	780	-	1545	165	3 996
Steam : backpressure turbine	82 789	70 488	3 039	2 621	22 166	693	5 755	12 034	339	8 864	-	2 789	2 909	2 481	10 111	7 436	1551
Steam : condensing turbine	30 073	22 231	74	5 134	7 048	-	171	2 020	-	6 024	-	460	2 489	1473	2 472	-	2 708
Gas turbine with heat recovery	16 165	13 937	686	600	6 149	218	2 049	2 583	88	1667	-	-	19	92	604	53	1357
Internal combustion engine	10 687	8 552	368	1343	2 506	-	1424	1211	32	550	30	2 062	150	151	68	54	738
Others	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**170 364**	**141 060**	**4 324**	**10 336**	**40 755**	**910**	**11 726**	**17 849**	**459**	**27 814**	**119**	**12 671**	**6 347**	**4 196**	**14 800**	**7 708**	**10 350**

Table 2: CHP heat production and capacity in EU Member States in the year 2000

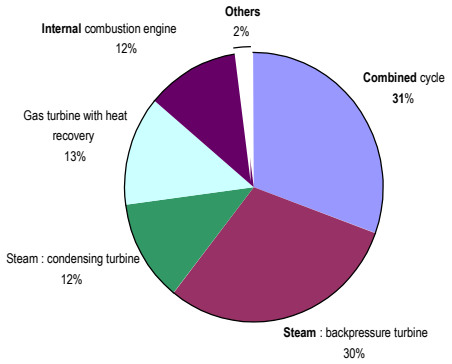
CHP generation and capacity by type of technology

Combined cycle plants generated 30.6% of CHP electricity and 19.7% of CHP heat in the EU. The contribution of steam backpressure turbines in generating CHP electricity was almost as high as that of combined cycles, 30.0%. On the other hand, the steam backpressure turbine plants produced much more CHP heat than the combined cycle plants, 1022 PJ (47.4%).

The share of CHP electricity generated in combined cycle plants is highest in the Netherlands (79.6%), Luxembourg (68.3%), the UK (52.0%), Italy (37.9%) and Spain (31.1%).

Steam backpressure turbine plants have the largest share of CHP electricity generation in Sweden (98.0%), Finland (49.6%), Germany (47.1%), Austria (38.7%) and France (35.1%).

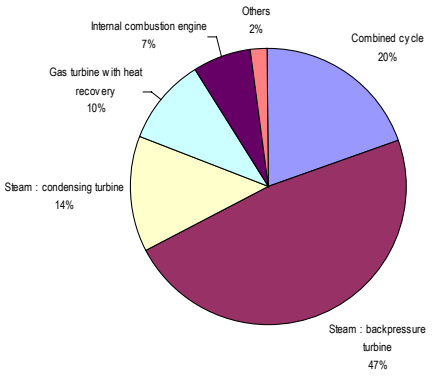
Gas turbines with heat recovery dominate CHP electricity generation in Ireland (66.8%), Belgium (62.3%) and Greece (58.4%).



CHP electricity generation in the EU

In Denmark steam condensing-extraction turbine plants have the largest share, 47.2%, and in Portugal internal combustion engines contribute the most to CHP electricity generation with a share of 40.9%.

Electrical capacity of steam backpressure turbine plants in the EU was somewhat higher than of combined cycle plants, 22.6 versus 19.5 GW_e. In heat capacity, steam backpressure turbine plants were clearly highest with 82.8 GW_{th} compared with 30.7 GW_{th} of combined cycle plants or 30.1 GW_{th} of steam condensing extraction plants.



CHP heat generation in the EU

CHP generation and capacity by economic activity

More than half of CHP electricity was produced in industrial plants, 145.3 TWh (58.4%), whilst public supply plants recorded CHP electricity generation of 103.5 TWh (41.6%).

Member States with a well-developed district-heating network have typically large CHP production by public supply. In Denmark, Belgium, Finland, Germany and Sweden more than half of the CHP electricity was generated in public supply plants. The other extremes are countries with more than 90% share of autoproducer plants: Spain, Ireland and Luxembourg (100%), Italy (95.5%) and the UK (95.2%).

Chemical industry (39.4 TWh), pulp and paper industry (34.0 TWh) and refineries (22.9 TWh) were the largest industrial CHP electricity generators. Two thirds of CHP electricity in industry was generated in these three sectors.

Division of CHP heat production on one hand between public supply and autoproducers and on the other hand between industrial sectors follows the shares of CHP electricity generation. 67.7% of CHP heat is produced in autoproducer plants and majority of that production takes place in pulp and paper industry (440.8 PJ), chemical industry (350.5 PJ) and in refineries (231.5 PJ).

Sector	Maximum CHP capacity		CHP Production		Fuel
	Electrical	Heat	Electricity	Heat	Input
	MW	MW	GWh	TJ	TJ(NCV)
Public supply	**39 355**	**63 942**	**103 459**	**695300**	**1778587**
Autoproducers	**36 158**	**106 421**	**145 279**	**1459616**	**3073072**
of which					
Mining and agglomeration of solid fuels	146	329	702	8644	20543
Extraction of crude oil and nat. gas	22	60	123	707	1923
Coke ovens	3	5	13	79	407
Refineries	5 104	15405	22 927	231505	450893
Iron and steel industry	788	2 759	3 170	28204	103108
Non-ferrous metals	47	149	199	2549	4657
Chemical industry	8 987	24 726	39 400	350499	781277
Non-metallic mineral products	407	617	2 337	16271	36989
Extraction	607	1278	3 106	34287	93318
Food products, beverages and tobacco	3 659	13 350	11285	121032	223627
Textile, clothing and leather	613	2 236	2 504	17509	38598
Paper and printing	6 704	25601	33 971	440840	743788
Metal products, machinery, equipment	483	770	1427	8335	26089
Other industrial branches	1133	2 412	4 101	29706	70082
Transport	25	42	101	608	2390
Services, etc	1753	3 267	7315	53487	115831
Others	5679	13 415	12 599	115355	359552
TOTAL	**75 513**	**170 363**	**248 738**	**2154916**	**4851659**

Table 3: CHP in the EU by economical activity in the year 2000

Fuel consumption in CHP generation

In the year 2000 47.0% of the fuel consumed in CHP plants was natural gas, which is clearly the fuel most commonly used in CHP generation in the EU. The share of solid and liquid fossil fuels has fallen over the course of time. In 2000 only 18% of the fuel input in CHP plants was hard coal, lignite or their derivatives. The share of renewables has remained at about 12%.

Natural gas was clearly the predominant fuel in seven Member States: Luxembourg (99.6%), Ireland (74.1%), Belgium (68.5%), the UK (68.0%), the Netherlands (63.6%), Italy (62.7%) and Spain (61.1%). Natural gas was also the most common fuel, though with a lower share, in Austria (46.2%) and in France (42.4%).

Coal, lignite and their derivatives were the most common types of fuel before natural gas in CHP generation in Greece (53.6%), Denmark (44.1%) and in Germany (43.7%).

Renewables were the most common fuel in CHP generation in Sweden (57.8%) and in Finland (45.0%). The large contribution of black liquor and wood wastes burned in CHP plants in pulp and paper industry explains the high shares of renewables in these two Nordic countries. The share of renewables is rather high also in Portugal (37.6%) France (27.9%) and Austria (18.3%).

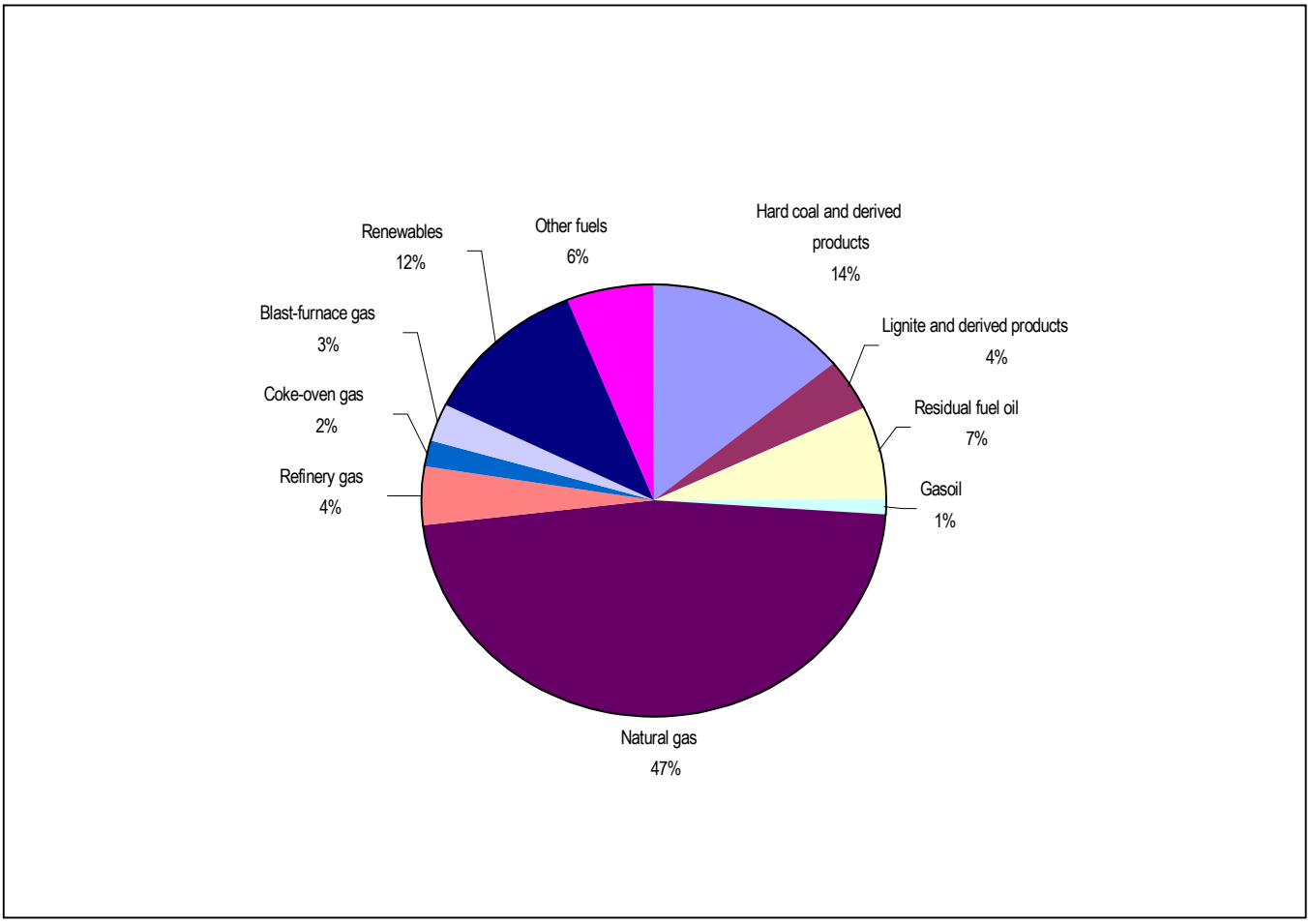
In Portugal the most common fuel is residual fuel oil since more than 40% of CHP electricity is generated in internal combustion engines.

Type of cycle	EU-15	Eurozone	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
Combined cycle	1338654	960923	4682	21759	95486	-	83064	-	-	313299	1790	353015	39131	-	70456	2235	353737
Steam: backpressure turbine	1633631	1354715	49720	48543	445489	32951	75735	204489	2543	127842	-	48002	63226	49419	288250	157390	40032
Steam: condensing turbine	956780	629002	2956	178790	98258	-	10074	51159	-	148144	-	132772	78878	27515	79246	-	148987
Gas turbine with heat recovery	469591	384221	36620	18125	96329	7766	97876	74523	5280	58316	-	-	437	2716	12123	983	58496
Internal combustion engine	371373	300938	4594	38115	70654	-	92901	34790	1099	14536	730	57754	3476	19697	706	395	31925
Others	81628	81628	-	-	81565	-	-	-	-	-	-	63	-	-	-	-	-
Total	**4851657**	**3711427**	**98572**	**305333**	**887781**	**40717**	**359650**	**364961**	**8923**	**662137**	**2520**	**591606**	**185149**	**99347**	**450781**	**161003**	**633177**
of which																	
Hard coal and derived products	693984	525184	2516	134709	306529	-	10197	19432	913	6053	-	88305	24641	-	66599	14732	19359
Lignite and derived products	176631	151466	-	-	81752	21844	-	-	892	14	-	-	12696	-	56112	3321	-
Residual fuel oil	344881	290105	6589	7097	14519	-	56985	38148	-	99681	-	506	12252	48342	13083	20359	27320
Gasoil	50027	46595	2020	335	6470	-	11088	1511	-	25003	9	253	15	16	210	1143	1954
Natural gas	2281458	1738053	67535	93608	301106	10798	219887	154896	6614	414835	2511	376047	85558	6129	102933	8426	430573
Refinery gas	212402	179754	-	2400	22934	-	23848	37594	492	33652	-	53513	3069	4489	163	-	30247
Coke-oven gas	92927	83477	2132	-	62707	-	2153	-	-	10483	-	1063	3846	1093	-	1022	8428
Blast-furnace gas	134216	86742	7999	-	36260	-	-	2582	-	19806	-	9715	7278	1482	1620	15916	31558
Renewables	564628	437102	8090	27721	18688	-	31272	101983	-	-	-	3158	33800	37336	202776	92981	6824
Other fuels	300502	172949	1692	39463	36816	8075	4220	8815	11	52610	-	59046	1995	460	7284	3101	76915

Table 4: Fuel consumption in CHP plants in EU Member States in the year 2000, TJ

Type of cycle	EU-15	Eurozone	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
Combined cycle	69.2	71.4	65.1	87.7	87.0	-	73.1	-	-	54.9	89.0	76.7	59.3	-	85.4	87.8	65.1
Steam: backpressure turbine	80.0	81.8	67.7	87.4	80.0	50.7	77.7	84.0	78.4	86.7	-	72.5	76.3	76.6	79.5	84.3	77.9
Steam: condensing turbine	56.2	61.7	62.3	62.8	35.0	-	69.3	65.8	-	59.0	-	41.5	59.8	82.2	70.0	-	54.1
Gas turbine with heat recovery	77.5	79.9	78.1	83.0	86.0	78.5	74.3	74.2	71.4	77.8	-	-	78.9	67.5	86.4	76.4	70.1
Internal combustion engine	75.2	80.4	75.6	86.7	80.0	-	68.5	76.2	77.3	76.0	78.6	80.0	65.7	55.4	78.3	74.9	73.2
Others	70.6	70.6	-	-	70.6	-	-	-	-	-	-	81.0	-	-	-	-	-
All plants	**71.5**	**75.1**	**71.7**	**72.7**	**75.6**	**56.0**	**73.1**	**78.7**	**74.1**	**64.5**	**86.0**	**68.8**	**65.5**	**73.7**	**78.9**	**84.2**	**64.2**

Table 5: Efficiencies of CHP plants in EU Member States in the year 2000, %



Fuel input to CHP plants in the EU-15

Performance of CHP plants

The overall efficiency of CHP plants in the EU was 71.5%. The efficiency was lowest in steam condensing-extraction plants, 56.2%. The heat production of condensing-extraction CHP plants can be adjusted to heat demand and even completely switched off, leaving them to generate only electricity. This naturally reduces their overall annual efficiency.

The efficiency of combined cycle plants was also rather low, 69.2%. Their efficiency depends strongly on design parameters: increasing the portion of electricity generation has a tendency to reduce their overall efficiency. Luxembourg, Sweden, Denmark, Germany and Finland report efficiencies in excess of 80% in combined cycle CHP plants, whilst in Italy and Austria the efficiency is below 60% and in the UK 65.1%.

The efficiencies of steam backpressure turbines (80.0%), gas turbines with heat recovery (77.5%) and internal combustion engines (75.2%) are greater than the average efficiency of all CHP plants in the EU. These three types of CHP plant are often used in industries with a fairly stable heat load, which in general terms explains the relatively high efficiencies. Greece makes an exception in backpressure turbine plants with a reported efficiency of 50.7%, which is related to combustion of low quality lignite.

The definition of CHP or "cogeneration" implies that heat and electricity are produced simultaneously in one process. In CHP production intermediate fluids, either hot steam or exhaust gases, are used first in electricity generation after which the remaining heat is recovered and not emitted to the environment. If some part of the intermediate fluid or the remaining thermal energy is ejected to the environment without heat recovery, the portion of the electricity generation corresponding to this part is by default not CHP electricity.

In separate electricity generation the conversion efficiency is between 35-55%, but in cogeneration plants overall efficiencies as high as 80-90% can be achieved by using the remaining thermal energy to produce heat either for industrial processes or district heating. The energy savings potential of cogeneration is important with regard to achieving the targets of the Kyoto protocol in reducing CO_2 emissions, improving energy efficiency and reducing dependence on imported energy in the EU.

There are many types of CHP plant in which the share of CHP electrical power can be changed on demand or whose operation can switch completely between CHP mode and electricity generation only. CHP plants are seldom equipped with any device to monitor CHP electricity generation, since it would require detailed measurements and thermodynamic calculations. Accordingly, indirect methods have been developed to calculate the CHP electricity generation.

The method used to calculate CHP electricity in the project for the year 2000 is based on the same principles as applied for the years 1994 – 1998. The most important change to the methodology was the introduction of overall efficiency of a CHP plant as a measure to determine whether the electricity generation is fully CHP or not. If the overall efficiency is above a threshold set at 75%, all the electricity generated is considered as CHP electricity. On the other hand, if the overall efficiency is below 75% the amount of CHP electricity, E_{CHP} is calculated as follows:

$$E_{CHP} = C \cdot H$$

Where

C is power-to-heat ratio characteristic of the plant

H is CHP heat generation of the plant.

Introducing the efficiency threshold has a quite significant effect on the results. Another new element introduced to the methodology was the provision of default power-to-heat ratios depending on the type of the plant, separate for district heating and industrial plants. The default values were used only if the real power-to-heat ratios were not known.

Abbreviations :

MWh	:	Megawatt hour (10^3 kWh)	MW	:	Megawatt
GWh	:	Gigawatt hour (10^6 kWh)	GW	:	Gigawatt
TWh	:	Terawatt hour (10^9 kWh)			
			GW_e	:	Gigawatt electric
TJ	:	Terajoule (10^9 kJ)	GW_{th}	:	Gigawatt thermal
PJ	:	Petajoule (10^{12} kJ)			

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