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Final report

Inventory of combined heat and power in Flanders 1990-2014

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Reference report on behalf of the Flemish Government
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SUMMARY OF THE INVENTORY OF COMBINED HEAT AND POWER

Grid map of combined heat and power in Flanders – 2014

The table below gives an overview of the key figures in relation to combined heat and power plants in Flanders in 2014.

	Engines	Gas turbines	Combined cycle gas turbines	Steam turbines Network-connected	Steam turbines Direct drive	TOTAL 2014	*Total 2013*
Electrical capacity [MW]	561	493	805	213	152	**2 223**	*2 193*
of which certifiable	557	368	751	147	54	***1 875***	*1 704*
Thermal capacity [MW]	694	735	583	850	937	**3 799**	*3 733*
Total production of electricity/power [PJ]	8.9	11.7	11.4	4.5	4.3	**40.7**	*44.2*
Total production of electricity/power [GWh]	2 469	3 239	3 170	1 239	1202	**11 318**	*12 288*
of which electricity [GWh]	2 467	3 223	3 170	1 239	0	**10 099**	*11 135*
% CHP electricity relative to gross domestic electricity consumption (*)	5 %	6 %	6 %	2 %	0 %	**18.4 %**	*19.9 %*
Total production of heat [PJ]	12.1	20.6	9.9	16.5	25.3	**84.5**	*83.9*
Total production of heat [GWh]	3 374	5 720	2 752	4 595	7 033	***23 474***	*23 294*
Electrical efficiency [%]	40 %	31 %	41 %	16 %	12 %	**27 %**	*28 %*
Thermal efficiency [%]	54 %	54 %	36 %	61 %	71 %	**56 %**	*54 %*
Overall efficiency [%]	94 %	85 %	77 %	78 %	83 %	**83 %**	*82 %*
Average hours of full load [h/a]	4 410	6 574	3 938	5 829	7 894	**5 096**	*5 642*
Combined heat and power savings [PJ] (**)	11	8.3	5.9	5.6	8.8	**39.8**	*38.8*
Combined heat and power savings [GWh] (**)	3 097	2 309	1 651	1 569	2 439	**11 065**	*10 769*
Relative primary energy savings [%] (**)	34.1 %	18.0 %	20.9 %	19.2 %	19.9 %	**22.0 %**	*21.5 %*

(*) Calculated as: final consumption (excluding self-production) + gross self-production + self-consumption in the processing industry + network losses.

(**) The combined heat and power savings are calculated on the basis of the European reference efficiencies based on the quantity of electricity from CHP pursuant to Annex II of the Energy Decree.

Key CHP facts in Flanders – 2014

The key facts about CHP in Flanders in 2014 are as follows:

- The operating CHP capacity (electrical and mechanical) in Flanders in 2014 was 2 223 MW. A total of 580 CHP plants were operational, spread across 467 sites.
- The operating CHP capacity (electrical and mechanical) in Flanders rose slightly in 2014. In 2013 the capacity was 2 193 MW. The number of gas turbines, combined cycle gas turbines and steam turbines remained unchanged. The increase resulted from the growing capacity of CHP engines, especially in agriculture. The capacity of engines under 50 kW_e rose from 529 MW_e in 2013 to 560 MW_e in 2014. The number of engines (excluding micro-engines) rose from 294 to 316.
- The number of installed micro-CHP plants fell from 121 to 116. The installed capacity of micro-CHP nonetheless increased slightly from 1.01 MW_e in 2013 to 1.03 MW_e in 2014.
- The total useful output of combined heat and power plants fell from 128.1 PJ in 2013 to 125.3 PJ in 2014. The production of CHP electricity/power fell by 8 % (from 44.2 PJ in 2013 to 40.7 PJ in 2014). This fall was mainly attributable to lower electricity production from gas-fired combined cycle power plants. The average hours of full load for combined cycle gas turbines was significantly lower in 2014 than in previous years. The percentage of CHP electricity within gross domestic electricity consumption fell from 19.9 % in 2013 to 18.4 % in 2014. Heat production in combined heat and power plants rose from 83.9 PJ in 2013 to 84.5 PJ in 2014.
- In 2014 around half of the useful energy was supplied in the form of steam (68.5 PJ). The quantity of heat produced in the form of hot water and hot air was 16.0 PJ. The production of electricity amounted to 36.4 PJ, while 4.4 PJ of power was produced.
- Total fuel consumption in 2014 was 150.8 PJ. Natural gas is the most important fuel for CHP in Flanders, making up 61 %. Gas turbines and combined cycle gas turbines were responsible for 44 % of total fuel

consumption in 2014, whereas steam turbines made up 42 % and engines 15 %.

- Over the period from 2006 to 2014, renewable CHP electricity/power rose from 0.5 PJ to 3.8 PJ. Over the same period, the quantity of renewable CHP heat rose from 1.5 PJ to 4.9 PJ. The proportion of renewable CHP electricity/power was 9.4 % in 2014. The renewable share of total CHP heat was 5.8 %.
- In 2014 total CHP savings amounted to 39.8 PJ. Relative primary energy savings amounted to 22.0 %, an increase on the figures for 2013 (21.5 %).

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

GDEC	Gross domestic electricity consumption
PES	Primary energy savings
RPES	Relative primary energy savings
CCGT	(Power plant with) combined cycle gas turbine
VREG	Flemish Electricity and Gas Market Regulator
VEA	The Flemish Energy Agency
CHPS	Combined heat and power savings
CHP	Combined heat and power

CHAPTER 1. INTRODUCTION

Combined heat and power (CHP) is a method of generating heat and electricity simultaneously in a single process, predominantly via a turbine or engine. This can lead to a reduction in fuel use compared to separate generation of heat in boilers and electricity in power plants. In Flanders, interest in CHP rose in the mid-1990s.

VITO has a reference mandate from the Flemish Government to inventorise CHP capacity in Flanders. An annual inventory is published which includes an analysis of CHP capacity, the useful energy produced by CHP and the primary energy savings resulting from CHP. This inventory provides an overview of developments over the period from 1990-2014.

In comparison with the previous report (September 2014), changes have been made for the years 2007 to 2013:

- The data on steam turbines for two companies have been corrected and supplemented. These amendments are effective from 2008 onwards.
- The figures for micro-CHP have been amended from 2009 as information on more installations has become available.
- The fuel type has been altered for a few CHP plants.
- The number of hours of full load and the CHP savings by type of plant have been recalculated for the period 2007-2013.
- The figures for production of CHP heat in 2009 have been adjusted.

CHAPTER 2. ANALYSIS OF CHP CAPACITY

2.1. Operating CHP capacity

The operating CHP capacity (electrical and mechanical) in Flanders in 2014 was 2 223 MW_{e+m}. The operating thermal capacity was 3 799 MW_{th}. A total of 580 CHP plants were in operation, across 467 CHP use sites (sites where CHP systems are installed).

The operating capacity includes CHP plants that were in use in 2014 for which operating data are available. Where CHP capacity was only in operation for part of the year it is nonetheless considered operating capacity.

Operating capacity, 2014	Electrical/mechanical capacity [MW_{e+m}]	Thermal capacity [MW_{th}]	Number of plants	Number of CHP use sites
Micro-engines	1.0	2.6	94	94
Engines (excluding micro-engines)	560	691	416	316
Gas turbines	493	735	17	17
Combined cycle gas turbines	805	583	13	6
Steam turbines; network-connected	213	850	23	18
Steam turbines; direct drive	152	937	17	16
TOTAL	**2 223**	**3 799**	**580**	**467**

Table 1. Overview of operating CHP capacity in Flanders in 2014

2.2. Installed CHP capacity

Table 2 provides an overview of the installed CHP capacity in Flanders as of 31 December 2014. The installed capacity also includes plants that were put out of service in 2014 (some temporarily) or that already have a VEA file but had not yet had certificates issued for them.

The installed electrical/mechanical CHP capacity was 2 242 MW, while the installed thermal capacity was 3 823 MW_{th}. There were 616 installed CHP plants, spread across 503 CHP use sites.

Of the 430 installed engines (excluding micro-engines), 416 were operational in 2014. Of the 116 installed micro-engines, 94 were operational. All the gas turbines, combined cycle gas turbines and steam turbines were operational.

Installed capacity 2014	Electrical/mechanical capacity [MW_{e+m}]	Thermal capacity [MW_{th}]	Number of plants	Number of CHP use sites
Micro-engines	1.0	3	116	116
Engines (excluding micro-engines)	579	715	430	330
Gas turbines	493	735	17	17
Combined cycle gas turbines	805	583	13	6
Steam turbines; network-connected	213	850	23	18
Steam turbines; direct drive	152	937	17	16
Total	**2 242**	**3 823**	**616**	**503**

Table 2. Overview of the installed CHP capacity in Flanders as of 31 December 2014

Plants with an electrical capacity below or equal to 50 kW_e are regarded as CHP micro-plants. These include, amongst other things, small farm digesters (pocket digesters), Stirling engines (external combustion engines) and piston engines running on natural gas, diesel or biofuel.

The installed capacity of micro-CHP increased slightly from 1.01 MW_e in 2013 to 1.03 MW_e in 2014 (see Table 3). The number of installed micro-CHP plants fell from 121 to 116. Stirling CHP engines have been used since 2010, by domestic households specifically. Due to technical issues, some of the Stirling engines were taken out of use again quite quickly after installation.

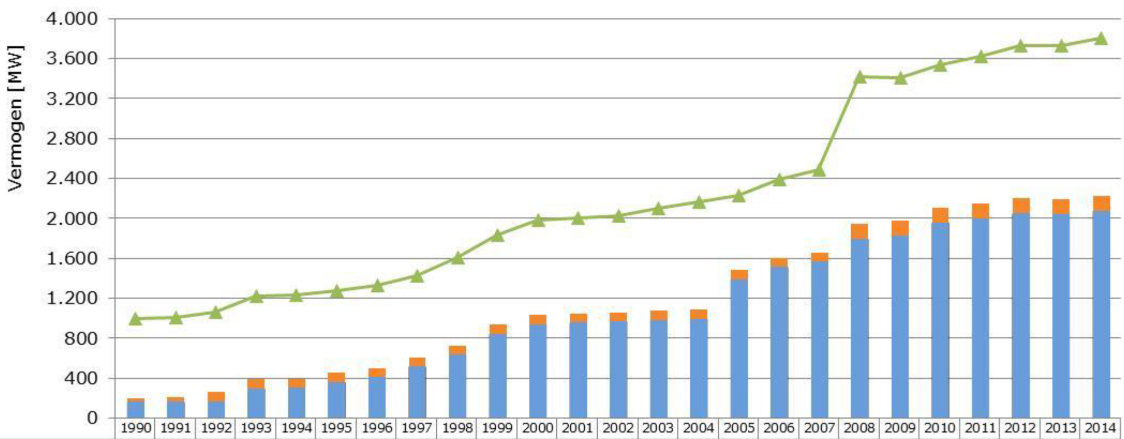
Installed CHP micro-plants, 2014		2008	2009	2010	2011	2012	2013	2014
Electrical capacity [MW_{e+m}]	Micro-engines (excluding Stirling engines)	0.10	0.20	0.23	0.47	0.87	0.98	1.00
	Stirling engines	0.00	0.00	0.01	0.03	0.06	0.04	0.03
	Total	**0.10**	**0.20**	**0.23**	**0.50**	**0.92**	**1.01**	**1.03**
Thermal capacity [MW_{th}]	Micro-engines (excluding Stirling engines)	0.15	0.31	0.36	0.80	2.17	2.57	2.63
	Stirling engines	0.00	0.00	0.04	0.26	0.46	0.30	0.24
	Total	**0.15**	**0.31**	**0.40**	**1.05**	**2.63**	**2.87**	**2.87**
Number of plants	Micro-engines (excluding Stirling engines)	16	21	24	37	77	86	88
	Stirling engines	0	0	5	30	53	35	28
	Total	**16**	**21**	**29**	**67**	**130**	**121**	**116**
Number of CHP use sites	Micro-engines (excluding Stirling engines)	16	21	24	37	77	86	88
	Stirling engines	0	0	5	30	53	35	28
	Total	**16**	**21**	**29**	**67**	**130**	**121**	**116**

Table 3. Evolution of the installed capacity of micro-CHP plants (2008-2014)

2.3. Evolution of operating thermal capacity

Figure 1 shows the development of operating CHP capacity in the period from 1990 to 2014. Up to and including 2007, there was gradual growth in CHP capacity. In 2008 there was strong growth in thermal capacity. In the subsequent period, CHP capacity experienced further strong growth.

In 2014 CHP capacity grew slightly to 2 223 MW_e+_m. In 2013 capacity was 2 193 MW_{e+m}. CHP capacity can be subdivided into 2 071 MW_e of electrical capacity and 152 MW_m of mechanical capacity from direct-drive steam turbines. In addition, individual engines also produce mechanical energy.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Mechanisch	40	45	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	154	153	153	153	152	152	152
Elektrisch	160	163	165	292	298	358	406	513	632	839	936	953	966	983	991	1.389	1.512	1.562	1.791	1.827	1.954	1.994	2.045	2.041	2.071
Thermisch	996	1.002	1.058	1.219	1.227	1.274	1.332	1.424	1.605	1.835	1.985	2.007	2.023	2.097	2.163	2.233	2.385	2.482	3.420	3.409	3.541	3.617	3.730	3.733	3.799

FIGURE 1: EVOLUTION OF OPERATING CHP CAPACITY IN FLANDERS (1990-2014)

<u>Key to figure</u>
Vermogen [MW] = Capacity [MW]
Mechanisch = Mechanical
Elektrisch = Electrical
Thermisch = Thermal

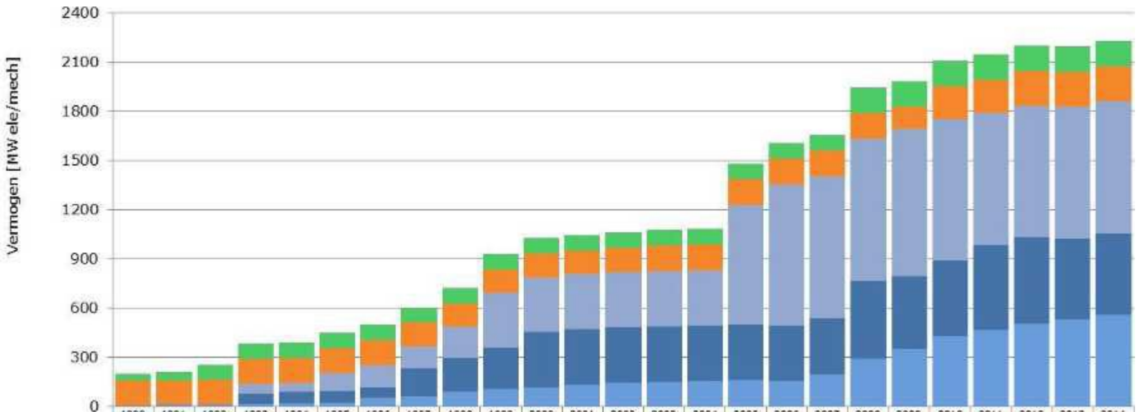
Table 4 shows the development of the number of CHP use sites (sites where CHP systems are installed), not including CHP micro-plants. The total number of CHP use sites increased from 351 in 2013 to 373 in 2014. The number of operating sites with engines increased from 294 to 316. The number of use sites with gas turbines, combined cycle gas turbines and steam turbines remained unchanged.

Number of operating CHP use sites	2007	2008	2009	2010	2011	2012	2013	2014	Difference from 2013 to 2014	
Engines (excluding micro-engines)	159	204	232	254	281	298	294	316	22	*7.5 %*
Gas turbines	10	11	12	13	17	17	17	17	0	*0.0 %*
Combined cycle gas turbines	7	7	7	7	6	6	6	6	0	*0.0 %*
Steam turbines; network-connected	20	20	18	18	18	18	18	18	0	*0.0 %*
Steam turbines; direct drive	11	16	16	16	16	16	16	16	0	*0.0 %*
TOTAL	**207**	**258**	**285**	**308**	**338**	**355**	**351**	**373**	**22**	***6.3 %***

Table 4. Evolution of the number of sites where CHP systems are installed (excluding CHP micro-plants, 2007-2014)

2.4. OPERATING CAPACITY BY TYPE OF TECHNOLOGY

Figure 2 shows the development of operating capacity by type of technology. The capacity of > 50 kW_e engines rose from 529 MW_e in 2013 to 560 MW_e in 2014. The operating capacity of micro-CHP rose from 0.9 to 1.0 MW_e. The capacity of other types of CHP remained unchanged.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Stoomturbines; directe aandrijving	40	45	91	91	91	91	91	91	91	91	91	91	91
Stoomturbines; netgekoppeld	152	152	152	152	152	152	152	146	146	146	146	146	146
STEGs	0	0	0	59	59	113	137	137	187	336	336	336	336
Gasturbines	0	0	0	66	66	66	66	169	209	251	337	337	337
Motoren (excl. micromotoren)	8	11	13	16	22	27	52	60	90	105	116	134	147
Micromotoren													

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Stoomturbines; directe aandrijving	91	91	91	91	91	154	153	153	153	152	152	152
Stoomturbines; netgekoppeld	158	160	160	155	159	159	136	201	205	210	213	213
STEGs	336	336	731	864	864	864	895	864	805	805	805	805
Gasturbines	337	337	337	337	344	474	445	460	520	526	493	493
Motoren (excl. micromotoren)	151	157	161	155	195	294	350	430	464	503	529	560
Micromotoren							0,0	0,0	0,1	0,6	0,9	1,0

FIGURE 2: EVOLUTION OF OPERATING ELECTRICAL AND MECHANICAL CHP CAPACITY IN FLANDERS (1990-2014)

<u>Key to figure</u>
Vermogen [MW ele/mech] = Capacity [MW electrical/mechanical]
Stoomturbines; directe aandrijving = Steam turbines; direct drive
Stoomturbines; netgekoppeld = Steam turbines; network-connected
STEGs = CCGTs
Gasturbines = Gas turbines
Motoren (excl. micromotoren) = Engines (excluding micro-engines)
Micromotoren = Micro-engines

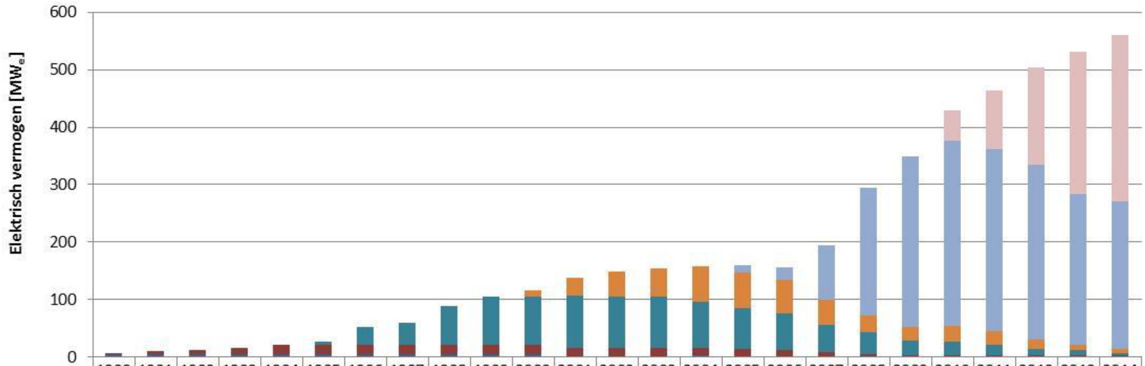
2.4.1. EVOLUTION OF CHP PLANTS WITH AN INTERNAL COMBUSTION ENGINE

Figure 3 shows the operating capacity of CHP systems with combustion engines by first year of CHP. This provides an insight into the age of the operating stock.

The first half of the 1990s were characterised by modest growth in the number of CHP systems with internal combustion engines. This growth accelerated from 1996. Between 2002 and 2004, overall capacity only grew slightly, and only limited replacement of stock took place. From 2005 more CHP use sites were taken out of use, while other, new ones went live. From 2007 the expansion and renovation of this type of CHP took off. In 2014 the total capacity of engines was 561 MW_e. 52 % of this (290 MW_e) was installed in the period 2010-2014, and 46 % (256 MW_e) in the period 2005-2009.

Figure 4 shows the number of operating CHP use sites by installed capacity (potentially with multiple CHP engines). In the early 1990s it was predominantly smaller CHP plants that entered service. From 1995 onwards the growth manifested itself in projects with ever greater capacity. Between 2001 and 2005 the number of use sites with an installed electrical capacity over 1 MW increased. This trend then continued in subsequent years.

For CHP micro-plants it is relatively common that there is no operating data available, as a result of which the plants in question are not included in the operating capacity calculated. The development of installed micro-CHP capacity is discussed in section 2.2.

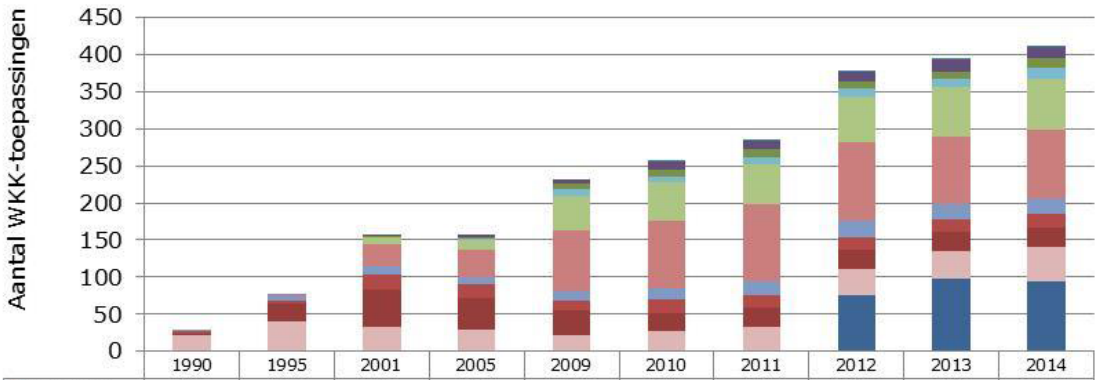


	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
2010-2014																					53	102	170	246	290
2005-2009																13	22	96	221	298	323	315	303	263	256
2000-2004											11	31	45	51	60	62	58	44	29	22	28	25	16	8	7
1995-1999						5	30	39	68	84	84	91	89	89	81	72	64	47	38	26	23	18	11	10	4
1990-1994	2	5	7	10	16	16	16	16	16	16	16	16	15	15	13	11	9	6	4	1	1	1	1	1	1
<1990	6	6	6	6	6	6	6	6	6	6	6		1	1	3	2	2	2	2	2	2	2	2	2	2

FIGURE 3: EVOLUTION OF OPERATING CAPACITY OF CHP SYSTEMS WITH COMBUSTION ENGINES (INCLUDING MICRO-CHP SYSTEMS) BY YEAR OF INSTALLATION (1990-2014)

Key to figure

Elektrisch vermogen [MW_e] = Electrical capacity [MW_e]



	1990	1995	2001	2005	2009	2010	2011	2012	2013	2014
10-20 MW	0	0	0	0	0	1	1	1	2	2
5-10 MW	0	0	3	3	6	10	11	12	16	15
4-5 MW	0	0	1	2	8	9	10	9	10	12
3-4 MW	0	0	1	3	8	8	9	12	10	15
2-3 MW	0	0	9	12	47	52	55	62	68	70
1-2 MW	0	1	29	37	81	92	104	105	91	92
0,75-1 MW	1	7	11	10	14	14	19	22	20	21
0,5-0,75 MW	4	3	21	19	13	18	17	17	17	19
0,25-0,5 MW	3	25	50	42	34	24	26	26	26	26
0,05-0,25 MW	21	40	33	29	21	26	30	35	37	46
Micro-WKK					0	2	2	76	98	94

FIGURE 4: EVOLUTION OF THE NUMBER OF OPERATING CHP USE SITES WITH A COMBUSTION ENGINE BY INSTALLED CAPACITY PER USE SITE (1990, 1995, 2001, 2005, 2009-2014)[1]

Key to figure

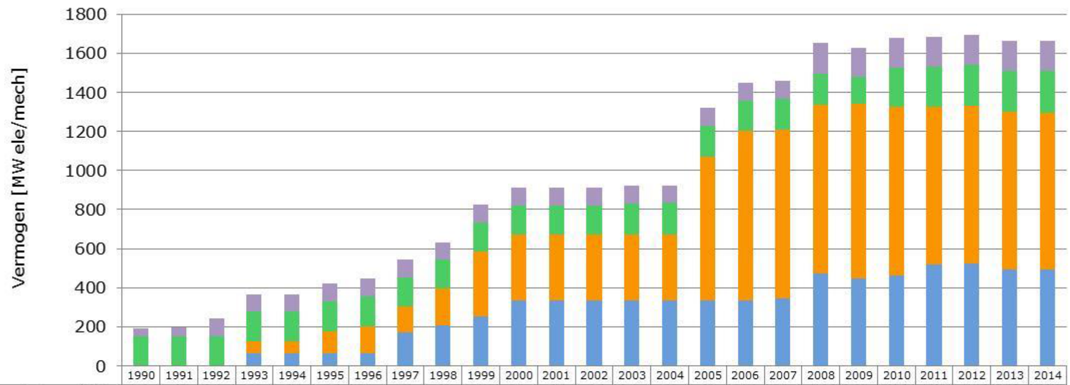
Aantal WKK-toepassingen = Number of CHP use sites

Mikro-WKK = Micro-CHP

2.4.2. EVOLUTION OF CHP PLANTS WITH GAS TURBINES, COMBINED CYCLE GAS TURBINES AND STEAM TURBINES

Figure 5 shows the development of CHP plants with a gas turbine, combined cycle gas turbine or steam turbine between 1990 and 2014. In 2014 the capacity of combined cycle gas turbines was 805 MW, the capacity of gas turbines was 493 MW and the capacity of network-connected steam turbines was 213 MW, while that of direct-drive steam turbines was 152 MW.

[1] The figures provide the capacity range, expressed in MW_e, greater than or equal to the lower value and less than the upper value. Micro-CHP is defined as CHP with a capacity below 50 kW_e.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Stoomturbines directe aandrijving	40	45	91	91	91	91	91	91	91	91	91	91
Stoomturbines netgekoppeld	152	152	152	152	152	152	152	146	146	146	146	146
STEG	0	0	0	59	59	113	137	137	187	336	336	336
Gasturbines	0	0	0	66	66	66	66	169	209	251	337	337

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Stoomturbines directe aandrijving	91	91	91	91	91	91	154	153	153	153	152	152	152
Stoomturbines netgekoppeld	146	158	160	160	155	159	159	136	201	205	210	213	213
STEG	336	336	336	731	864	864	864	895	864	805	805	805	805
Gasturbines	337	337	337	337	337	344	474	445	460	520	526	493	493

Figure 5: Evolution of the operating capacity of CHP plants with gas turbines, combined cycle gas turbines and steam turbines (1990-2014)

<u>Key to figure</u>

Vermogen [MW ele/mech] = Capacity [MW electrical/mechanical]

Stoomturbines directe aandrijving = Steam turbines; direct drive

Stoomturbines netgekoppeld = Steam turbines; network-connected

STEG = CCGTs

Gasturbines = Gas turbines

The first projects with gas turbines and combined cycle gas turbines date from 1993. From then up to the year 2000, the number of projects rose significantly; the installed capacity in 2000 (911 MW_e) was more than twice that of 1993 (367 MW_e). Between 2000 and 2004, growth stagnated almost entirely. With the entry into service of a 395 MW_e capacity installation in 2005, the CHP capacity with turbines increased sharply again. The growth continued in 2006 and 2008. Since then, the total turbine capacity has been relatively stable. In 2014 no capacity was added.

Figure 6 shows the evolution of the thermal capacity of CHP plants with gas turbines, combined cycle gas turbines and steam turbines.

FIGURE 6: EVOLUTION OF THE OPERATING THERMAL CAPACITY OF CHP PLANTS WITH GAS TURBINES, COMBINED CYCLE GAS TURBINES AND STEAM TURBINES (1990-2014)

Key to figure

Thermisch vermogen [MW] = Thermal capacity [MW]

Stoomturbines directe aandrijving = Steam turbines; direct drive

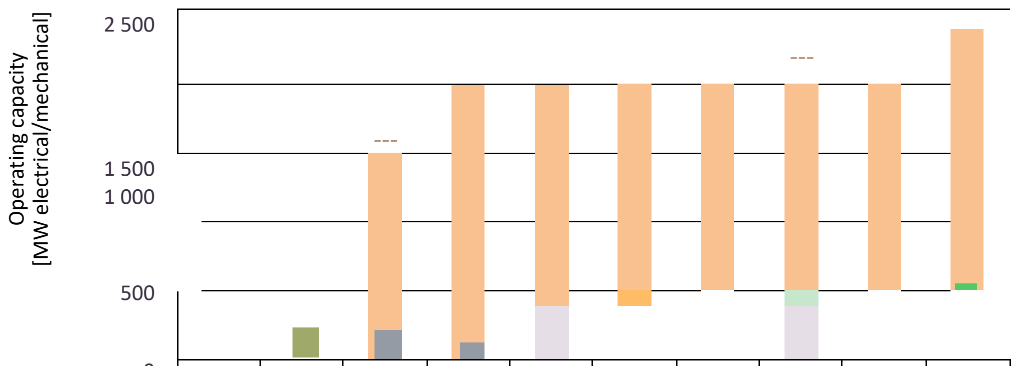
Stoomturbines netgekoppeld = Steam turbines; network-connected

STEG = CCGTs

Gasturbines = Gas turbines

2.5. OPERATING CAPACITY BY SECTOR

Figure 7 shows the operating capacity of CHP plants by sector. We assume that the plants have not changed sector since they entered service.



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
■ Residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
■ Industry – Gas and/or steam turbines	1 265	1 393	1 404	1 575	1 571	1 619	1 624	1 635	1 604	1 604
■ Industry – Engines	61	59	64	65	61	58	73	60	61	60
■ Tertiary sector	68	66	64	64	69	69	83	99	95	97
■ Agriculture	74	73	106	205	263	320	333	370	391	415
■ Waste processing	12	12	16	14	15	42	33	33	41	48

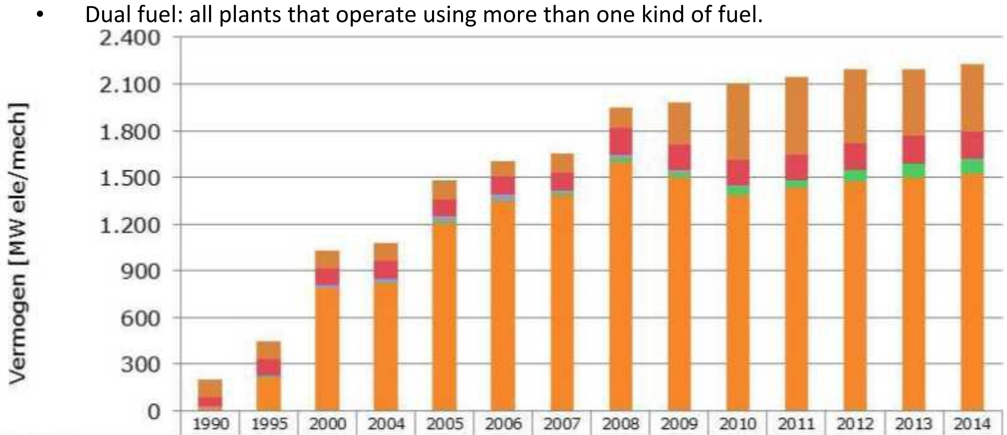
FIGURE 7: EVOLUTION OF OPERATING ELECTRICAL/MECHANICAL CHP CAPACITY BY SECTOR IN FLANDERS (INCLUDING MICRO-CHP) (2005-2014)

The operating capacity in the agricultural sector has been exhibiting a continuous upward trend as a result of the growing use of CHP plants with internal combustion engines. In 2005 the operating capacity in this sector was still only 74 MW_e. By 2014 capacity had risen to 415 MW_e. The operating capacity of CHP plants in the tertiary sector was 97 MW in 2014, including a 54 MW_e combined cycle gas turbine plant. Operating capacity in the waste-processing sector rose from 41 to 48 MW.

2.6. OPERATING CAPACITY BY FUEL TYPE

Figure 8 shows the operating capacity by fuel type:

- Natural gas;
- Biogas and landfill gas;
- Liquid fuels: fossils (heavy and light fuel oil) and renewable (rapeseed oil and palm oil);
- Recovery steam;
- Dual fuel: all plants that operate using more than one kind of fuel.



	1990	1995	2000	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Dual fuel	115	115	111	118	121	98	122	130	273	496	499	477	429	434
Recuperatiestoom	56	108	108	112	112	117	112	172	163	163	164	171	173	173
Vloeibare brandstoffen	6	12	22	28	26	35	16	20	11	6	6	4	3	3
Biogas en stortgas	1	2	5	10	16	15	19	29	39	58	48	72	87	92
Aardgas	22	212	781	813	1205	1339	1383	1593	1494	1384	1429	1473	1500	1520

FIGURE 8: EVOLUTION OF OPERATING ELECTRICAL/MECHANICAL CHP CAPACITY BY FUEL TYPE IN FLANDERS (INCLUDING MICRO-CHP) (1990, 1995, 2000, 2004-2014)

<u>Key to figure</u>
Vermogen [MW ele/mech] = Capacity [MW electrical/mechanical]
Dual fuel = Dual fuel
Recuperatiestoom = Recovery steam
Vloeibare brandstoffen = Liquid fuels
Biogas en stortgas = Biogas and landfill gas
Aardgas = Natural gas

Plants with a capacity of 434 MW operated using more than one kind of fuel (dual fuel). In 2014 the capacity of technologies operating exclusively on natural gas was 1 520 MW. The capacity of plants operating on biogas and landfill gas was 92 MW. The capacity of operating CHP plants powered by recovery steam (steam turbines) was 173 MW in 2014.

Instead of allocating the capacity to a specific fuel, it is also possible to consider the fuel input itself. Total fuel consumption in 2014 was 150.8 PJ. Gas turbines and combined cycle gas turbines were responsible for 44 % of total fuel consumption in 2014, whereas steam turbines made up 42 % and engines 15 %.

Natural gas is the most important fuel for CHP plants in Flanders, making up 61 %, followed by recovery steam. The share taken up by liquid fuels (both fossil and renewable) is limited. Biogas and landfill gas, as well as other fuels, namely oils and fats, sludge, wood, refinery gas, waste and coal, are responsible for the remaining fuel input.

Table 5. Evolution of fuel input for CHP plants by type of technology (2007-2014)

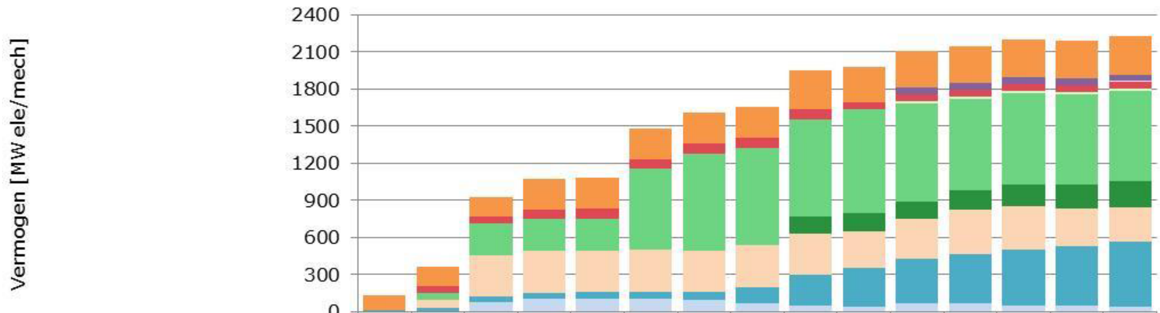
	2007		2008		2009		2010		2011		2012		2013		2014	
	[TJ]	[%]	[TJ]	[%]	[TJ]	[%]	[TJ]	[%]	[TJ]	[%]	[TJ]	[%]	[TJ]	[%]	[TJ]	[%]
Engines	**5 608**	**4.8 %**	**9 485**	**7.4 %**	**13 579**	**9.6 %**	**19 252**	**11.9 %**	**19 626**	**12.6 %**	**22 081**	**13.0 %**	**22 927**	**14.7 %**	**22 446**	**14.9 %**
Natural gas	4 456	3.8 %	8 266	6.4 %	11 086	7.9 %	14 389	8.9 %	15 378	9.8 %	16 996	10.0 %	17 166	11.0 %	16 345	10.8 %
Biogas and landfill gas	725	0.6 %	864	0.7 %	1 946	1.4 %	3 025	1.9 %	2 744	1.8 %	3 713	2.2 %	4 982	3.2 %	5 554	3.7 %
Biomass	0	0.0 %	0	0.0 %	0	0.0 %	1 132	0.7 %	1 152	0.7 %	1 132	0.7 %	588	0.4 %	370	0.2 %
Rapeseed oil and palm oil	274	0.2 %	249	0.2 %	372	0.3 %	581	0.4 %	231	0.1 %	181	0.1 %	143	0.1 %	120	0.1 %
Oils and fats		0.0 %		0.0 %	81	0.1 %	37	0.0 %	0	0.0 %	0	0.0 %	0	0.0 %	0	0.0 %
Light fuel oil	153	0.1 %	106	0.1 %	94	0.1 %	89	0.1 %	122	0.1 %	59	0.0 %	47	0.0 %	57	0.0 %
Gas turbines and CCGTs	**65 894**	**56.0 %**	**67 917**	**52.9 %**	**80 688**	**57.3 %**	**82 559**	**51.0 %**	**79 625**	**51.0 %**	**84 942**	**50.0 %**	**72 606**	**46.5 %**	**65 674**	**43.5 %**
Natural gas	65 854	56.0 %	67 917	52.9 %	80 101	56.9 %	79 840	49.4 %	77 396	49.6 %	81 266	47.8 %	70 324	45.0 %	62 949	41.7 %
Other fuels	40	0.0 %	0	0.0 %	587	0.4 %	2 719	1.7 %	2 229	1.4 %	3 676	2.2 %	2 282	1.5 %	2 725	1.8 %
Steam turbines	**46 162**	**39.2 %**	**51 072**	**39.8 %**	**46 483**	**33.0 %**	**59 951**	**37.1 %**	**56 912**	**36.4 %**	**63 002**	**37.1 %**	**60 745**	**38.9 %**	**62 689**	**41.6 %**
Natural gas	10 135	8. %	10 290	8.0 %	9 914	7.0 %	13 476	8.3 %	12 071	7.7 %	13 417	7.9 %	13 182	8.4 %	12 890	8.5 %
Biogas	42	0.0 %	33	0.0 %	45	0.0 %	50	0.0 %	132	0.1 %	157	0.1 %	148	0.1 %	181	0.1 %
Heavy fuel oil	2 074	1.8 %	1 361	1.1 %	694	0.5 %	0	0.0 %	6	0.0 %	0	0.0 %	0	0.0 %	0	0.0 %
Light fuel oil	47	0.0 %	16	0.0 %	76	0.1 %	0	0.0 %	1	0.0 %	0	0.0 %	5	0.0 %	1	0.0 %
Oils and fats, sludge, wood	3 836	3.3 %	3 094	2.4 %	2 351	1.7 %	3 886	2.4 %	4 950	3.2 %	5 959	3.5 %	5 992	3.8 %	6 394	4.2 %
Recovery steam	27 800	23.6 %	33 294	25.9 %	30 387	21.6 %	37 251	23.0 %	35 516	22.7 %	40 042	23.6 %	35 764	22.9 %	37 824	25.1 %
Coal	2 228	1.9 %	2 560	2.0 %	2 291	1.6 %	2 656	1.6 %	2 578	1.7 %	2 603	1.5 %	2 154	1.4 %	2 059	1.4 %
Other fuels	0	0.0 %	426	0.3 %	724	0.5 %	2 633	1.6 %	1 658	1.1 %	824	0.5 %	3 499	2.2 %	3 340	2.2 %
TOTAL	**117 664**	**100 %**	**128 475**	**100 %**	**140 750**	**100 %**	**161 762**	**100 %**	**156 163**	**100 %**	**170 025**	**100 %**	**156 278**	**100 %**	**150 808**	**100 %**

2.7. OPERATING CAPACITY BY TYPE OF MANAGEMENT

The figure below shows the split between electrical/mechanical capacity by type of technology and management type. We assume that the plants have not changed management type since they entered service.

An independent producer is an enterprise whose primary activity is to produce electrical power for the sole purpose of selling this to a distributor or via a third party to consumers. A self-producer is a company or business that produces electricity itself, alongside its primary activity, for its own use and possibly for sale to other parties.[2] Plants that are operated by self-producers are categorised as user-managed plants. Whenever a CHP plant is operated in collaboration with a power company, the form of management is listed as collaboration. A public producer is a publicly-owned enterprise whose primary activity is to produce electrical power for the purpose of selling this to a distributor or via a third party to consumers.

The capacity of engines operated in collaboration was 38 MW in 2014. At 523 MW, user-managed capacity is significantly larger. Up to 2006 all gas turbines were operated in collaboration with an electricity producer. This has changed since 2007, and the capacity of user-managed gas turbines is on the rise. In 2014 310 MW of steam turbines were user-operated, 51 MW were operated in collaboration and 4 MW were operated by independent producers.



	1990	1995	2000	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Stoomturbines - eigen beheer	126	159	159	250	252	252	242	246	308	285	299	303	308	310	310
Stoomturbines - samenwerking								0	0	0	51	51	51	51	51
Stoomturbines - autonome producent	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4
STEG - publieke producent	0	54	54	78	78	78	78	78	78	54	54	54	54	54	54
STEG - eigen beheer				0	0	0	0	0	0	0	19	19	19	19	19
STEG - samenwerking	0	59	259	259	259	654	787	787	787	841	791	732	732	732	732
Gasturbines - eigen beheer	0	0	0	0	0	0	0	7	137	145	145	162	183	196	210
Gasturbines - samenwerking	0	66	337	337	337	337	337	337	337	300	315	358	343	298	282
Motoren - eigen beheer	8	23	46	51	51	59	66	128	247	308	365	402	459	485	523
Motoren - samenwerking/autonome producent	0	4	70	100	106	102	89	67	47	42	64	61	44	45	38

FIGURE 9: EVOLUTION OF INSTALLED ELECTRICAL/MECHANICAL CHP CAPACITY BY TYPE OF TECHNOLOGY AND MANAGEMENT TYPE IN FLANDERS (1990, 1995, 2000, 2003-2014)

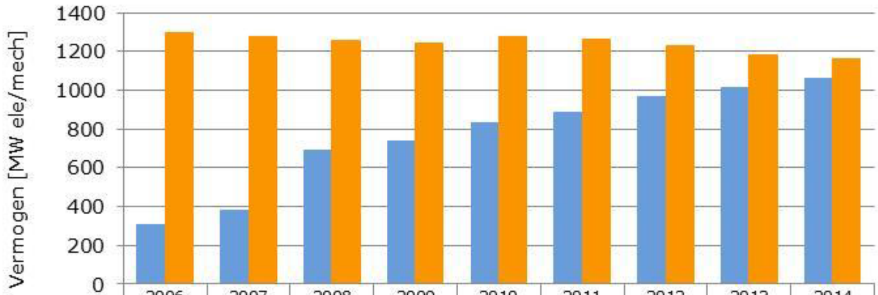
<u>Key to figure</u>

Vermogen [MW ele/mech] = Capacity [MW electrical/mechanical]
Stoomturbines – eigen beheer = Steam turbines – user-managed
Stoomturbines – samenwerking = Steam turbines – collaboration
Stoomturbines – autonome producent = Steam turbines – independent producer

[2] However, in recent years this definition has been diluted: many plants are indeed located with the end-user, but an end-user of the heat produced.

STEG – publieke producent = CCGTs – public producer
STEG – eigen beheer = CCGTs – user-managed
STEG – samenwerking = CCGTs – collaboration
Gasturbines – eigen beheer = Gas turbines – user-managed
Gasturbines – samenwerking = Gas turbines – collaboration
Motoren – eigen beheer = Engines – user-managed
Motoren – samenwerking/Autonome producent = Engines – collaboration/independent producer

Total user-managed capacity in 2014 was 1 063 MW (see Figure 10). The increase in user-managed capacity over recent years can be explained, to a significant extent, by the increase in the number of CHP plants with internal combustion engines, which are mostly operated as user-managed plants.



	2006	2007	2008	2009	2010	2011	2012	2013	2014
Eigen beheer	308	381	692	738	828	886	969	1010	1063
Samenwerking / Publieke producent / Autonome producent	1295	1273	1252	1242	1279	1260	1228	1183	1161

FIGURE 10: EVOLUTION OF OPERATING CHP CAPACITY IN FLANDERS BY MANAGEMENT TYPE (2006-2014)

<u>Key to figure</u>
Vermogen [MW ele/mech] = Capacity [MW electrical/mechanical]
Eigen beheer = User-managed
Samenwerking / Publieke producent / Autonome producent = Collaboration/Public producer/Independent producer

2.8. OPERATING CAPACITY BY EFFICIENCY CLASS

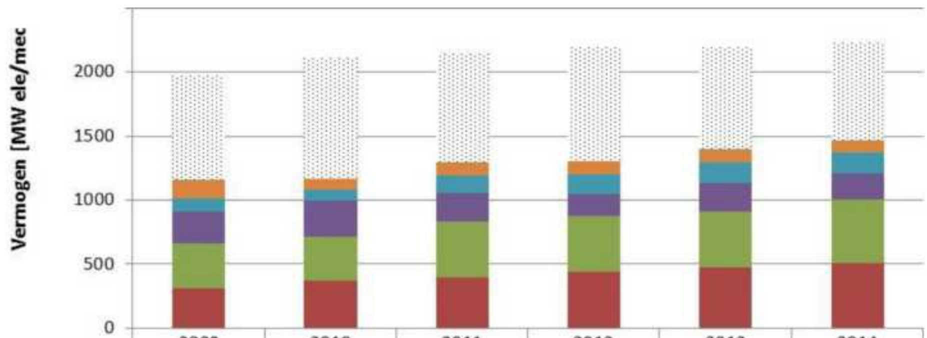
The figure below shows, by technology type, what capacity each year obtains a total efficiency (combined production of electricity and heat versus fuel input) of at least 80 % for combined cycle gas turbines and condensing steam turbines with bleeding or 75 % for all other types of technology.[3] This is a measure of quality for the CHP operating stock.

In total, in 2014 66 % of the installed capacity enjoyed an overall efficiency above the threshold value. In 2013 this proportion was only 64 %. There are significant differences to be seen between the different technologies:

- 91 % of capacity in engines (excluding micro-engines) has an efficiency over 75 %. For micro-engines, this proportion is 98 %;
- 100 % of capacity in gas turbines has an efficiency over 75 %;

[3] These percentages were included unchanged in the new directive, Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

- 25 % of capacity in combined cycle gas turbines has an efficiency over 80 %;
- 77 % of the capacity in network-connected steam turbines is high-efficiency.
- 65 % of the capacity in direct-drive steam turbines is high-efficiency.



	2009	2010	2011	2012	2013	2014
Niet-hoogrenderend vermogen	824	944	856	899	800	758
Stoomturbines; directe aandrijving	147	88	99	98	98	98
Stoomturbines; netgekoppeld	97	85	138	157	163	163
STEGs	254	282	222	168	223	204
Gasturbines	351	340	434	440	438	493
Motoren (excl. micromotoren)	307	368	398	435	470	508
Micromotoren	0	0	0	0	1	1

Figure 11: Evolution of high-efficiency (overall efficiency over 75 or 80 %) operating CHP capacity by type of technology in Flanders (2009-2014)

Key to figure

Vermogen [MW ele/mech] = Capacity [MW electrical/mechanical]

Niet-hoogrenderend vermogen = Non-high-efficiency capacity

Stoomturbines; directe aandrijving = Steam turbines; direct drive

Stoomturbines; netgekoppeld = Steam turbines; network-connected

STEGs = CCGTs

Gasturbines = Gas turbines

Motoren (excl. micromotoren) = Engines (excluding micro-engines)

Micromotoren = Micro-engines

Percentage of capacity that is high-efficiency	2009	2010	2011	2012	2013	2014
Micro-engines	-	100 %	100 %	77 %	99 %	98 %
Engines (excluding micro-engines)	88 %	86 %	86 %	86 %	89 %	91 %
Gas turbines	79 %	74 %	83 %	84 %	89 %	100 %
Combined cycle gas turbines	28 %	33 %	28 %	21 %	28 %	25 %
Steam turbines; network-connected	71 %	42 %	67 %	74 %	77 %	77 %
Steam turbines; direct drive	96 %	58 %	65 %	65 %	65 %	65 %
TOTAL	*58 %*	55 %	60 %	59 %	64 %	66 %

Table 6. Evolution of the percentage: operating CHP capacity by type of technology with an overall efficiency above the threshold value in Flanders (2009-2014)

2.9. OPERATING CERTIFIABLE CAPACITY

The Flemish Government wants to promote primary energy savings by means of high-quality CHP plants. Owners of high-quality CHP plants could be eligible for CHP certificates. Electricity suppliers are required to submit a certain number of CHP certificates.

Two criteria are used as the basis for determining the certifiability of CHP plants:

1. Directive 2012/27/EU – Annex II: Methodology for determining the efficiency of the cogeneration process [1]:

   - This requires that
     - CHP plants with an electrical capacity of 1 MW or below provide primary energy savings,

and;
- o CHP plants with an electrical capacity of over 1 MW provide primary energy savings of at least 10 %.

2. Furthermore, point (c) of Annex II to the Directive also requires that cogeneration units with an electrical capacity greater than 25 MW must have an overall efficiency above 70 %.
3. Flemish Government Decree of 19 November 2010 [2]:
   - This decree transposes the quality requirements of the Directive in Article 6.2.3 and in Annex I. Article 6.2.12 also lays down the requirement that the plant must first enter into service or be substantially modified after 1 January 2002, by way of implementation of Article 7.1.2.(4) of the Flemish Energy Decree of 8 May 2009.

These calculations are based on a comparison between the electrical (or mechanical) and thermal efficiencies of the CHP plant and a reference plant. The last of these varies according to the year of construction, type of technology, fuel used, use of heat, climatic conditions, degree of network connection and percentage of electricity delivered to the public grid, as described in Directive 2012/27/EU [1].

The table below provides an overview of the capacity of VEA-approved production plants that are eligible for acceptable CHP certificates, together with their installed capacity by type of technology The total certified capacity was 1 875 MW in 2014. That represents 84 % of the installed CHP capacity in 2014 (2 242 MW).

2014	Certified capacity [MW_e]
Micro-engines	1
Engines (excluding micro-engines)	556
Gas turbines	368
Combined cycle gas turbines	751
Steam turbines; network-connected	147
Steam turbines; direct drive	54
Total	**1 875**

Table 7. Capacity of VEA-approved CHP plants that are eligible for Flemish CHP certificates (2014)

Table 8 shows the number of CHP certificates by year of production expressed in millions of certificates. After the number of certificates issued rose every year up to 2013, in 2014 the number of certificates issued (5.54 million) was lower than in the preceding year (5.82 million).

	Number of acceptable CHP certificates issued
2006	459 582
2007	1 134 177
2008	2 149 405
2009	3 336 088
2010	4 656 555
2011	5 210 256
2012	5 649 348
2013	5 816 745
2014	5 540 021

Table 8: Number of CHP certificates that are acceptable with regard to the certification obligation (2006-2014). Source: VREG, 3 June 2015

CHAPTER 3. ANALYSIS OF THE USEFUL ENERGY PRODUCED BY CHP

This chapter will examine how much heat and power CHP plants generate. It will also discuss how much CHP electricity and CHP heat can be categorised as renewable.

3.1. USEFUL ENERGY PRODUCED BY CHP

Table 9 shows the evolution of the output of useful energy by type of Flemish CHP over the period 2005-2014. Over the preceding years, insufficient reliable data were available to be able to carry out the same analysis. For CHP micro-plants, a separate sub-table has been added showing data for the years 2012-2014.

In 2014 all the CHP plants together produced 125.3 PJ of useful energy. The quantity of useful energy is divided into heat (hot water and hot air), steam, electricity and power (namely the direct driving of machinery).

[PJ]	2005		2006		2007		2008		2009	
In	**109.4**		**113.5**		**117.7**		**128.5**		**140.7**	
Hot water/ hot air	2.3	2.6 %	3.3	3.7 %	3.7	3.9 %	5.4	5.2 %	9.7	8.3 %
Steam	56.2	64.6 %	53.9	59.6 %	55.4	58.8 %	61.1	58.6 %	64.8	55.1 %
Electricity	25.2	*29.0 %*	30.4	33.6 %	32.3	34.3 %	34.2	32.8 %	39.2	33.4 %
Power	3.3	*3.8 %*	2.8	3.1 %	2.8	2.9 %	3.6	3.4 %	3.8	3.2 %
Total out	**87.0**	***100 %***	**90.4**	**100 %**	**94.2**	**100 %**	**104.2**	**100 %**	**117.5**	**100 %**
Loss	22.4	*20.5 %*	23.0	20.3 %	23.5	20.0 %	24.3	18.9 %	23.2	16.5 %

[PJ]	2010		2011		2012		2013		2014	
In	**161.8**		**156.2**		**170.0**		**156.3**		**150.8**	
Hot water/ hot air	12.4	*9.4 %*	13.9	11.1 %	17.0	12.6 %	16.4	12.8 %	16.0	12.8 %
Steam	72.0	*54.6 %*	65.2	52.0 %	68.1	50.5 %	67.5	52.7 %	68.5	54.7 %
Electricity	43.7	*33.1 %*	41.9	33.4 %	45.2	33.6 %	40.1	31.3 %	36.4	29.0 %
Power	3.9	*3.0 %*	4.3	3.4 %	4.4	3.3 %	4.2	3.2 %	4.4	3.5 %
Total out	**132.0**	**100 %**	**125.2**	**100 %**	**134.7**	**100 %**	**128.1**	**100 %**	**125.3**	**100 %**
Loss	29.8	18.4 %	30.9	20 %	35.3	21 %	28.2	18 %	25.6	17 %

Table 9. Evolution of the input and output of useful energy from CHP (including micro-CHP, 2005-2014)[4]

[TJ]	2012	2013	2014
In	**20.7**	**51.8**	**56.3**
Hot water/ hot air	10.5 72.3 %	34.9 75.1 %	37.9 74.6 %
Steam	0.0 0.0 %	0.0 0.0 %	0.0 0.0 %
Electricity	4.0 27.7 %	11.5 24.7 %	12.9 25.3 %
Power	0.0 0.0 %	0.1 0.2 %	0.1 0.1 %
Total out	**14.5 100 %**	**46.5 100 %**	**50.8 100 %**
Loss	6.1 30 %	5.4 10 %	5.5 10 %

Table 10. Evolution of the input and output of useful energy from micro-CHP (2012-2014)[5]

These data from 2014 allow the following conclusions to be drawn:

- The total useful output from CHP plants fell from 128.1 PJ in 2013 to 125.3 PJ in 2014. In 2014 the production of CHP electricity/power fell by 8 % compared to 2013. This fall was mainly attributable to lower electricity production from gas-fired combined cycle power plants. The average hours of full load for combined cycle gas turbines was significantly lower in 2014 than in previous years (see 3.2).
- Over half of the useful energy is supplied in the form of steam. In 2014 steam production was 68.5 PJ.

[4] The shares of heat, steam, electricity and power are in relation to total useful output. The percentage loss is calculated in relation to the input.

[5] The shares of heat, steam, electricity and power are in relation to total useful output. The percentage loss is calculated in relation to the input.

- In 2014 the quantity of heat produced in the form of hot water and hot air was 16.0 PJ. Over the years, this has increased in connection with the increased use of CHP plants with engines.
- At 36.4 PJ, electricity made up 29 % of useful output. Production of power amounted to 4.4 PJ.
- Energy losses were 17 % in 2014. This means that the average overall efficiency of the CHP plants was 83 %.
- The output from CHP micro-plants increased from 14.5 TJ in 2012 to 50.8 TJ in 2015. Around 75 % of the output from CHP micro-plants is heat, with around 25 % being electricity.

The figure below provides a diagrammatic overview of the fuel input, the output and the losses for all CHP plants in 2014.

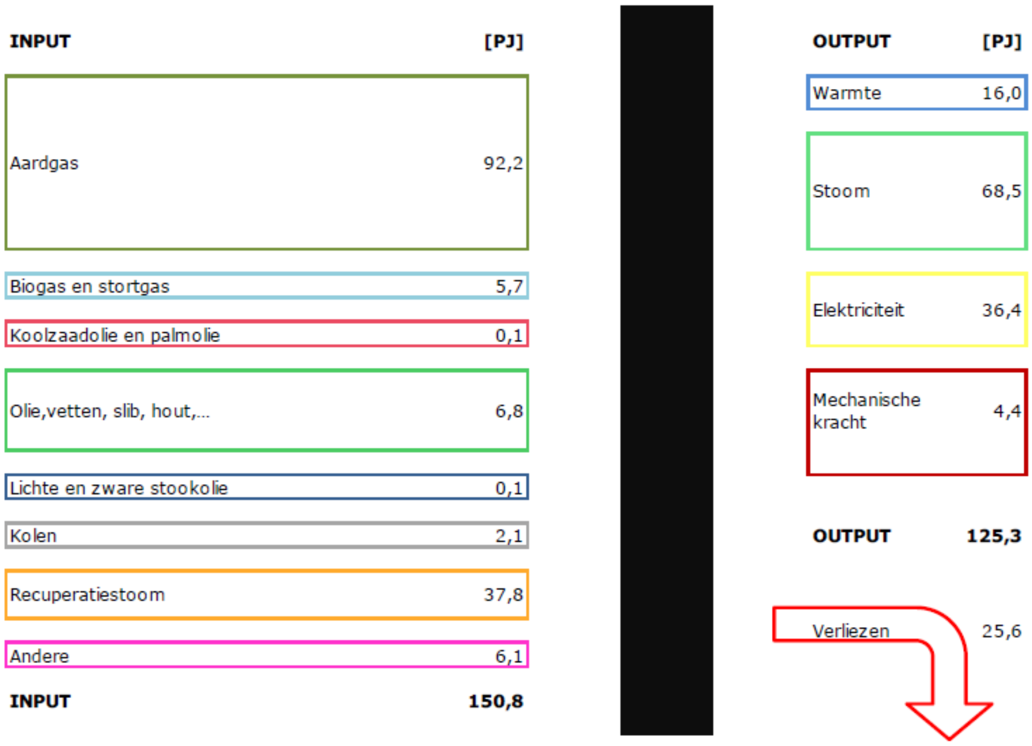


FIGURE 12: INPUT/OUTPUT DIAGRAM FOR FLEMISH CHP PLANTS (INCLUDING MICRO-CHP, 2014)

<u>Key to figure</u>
Input
Aardgas = Natural gas
Biogas en stortgas = Biogas and landfill gas
Koolzaadolie en palmolie = Rapeseed oil and palm oil
Olie, vetten, slib, hout, … = Oils and fats, sludge, wood, etc.
Lichte en zware stookolie = Light and heavy fuel oil
Kolen = Coal
Recuperatiestoom = Recovery steam
Andere = Other
Input

Output

Warmte = Heat
Stoom = Steam
Elektriciteit = Electricity
Mechanische kracht = Mechanical power
Output
Verliezen = Losses

3.2. USEFUL ENERGY PRODUCED BY CHP BY TECHNOLOGY TYPE

The table below gives an overview of the quantity of useful energy that CHP plants in Flanders produced in 2014. It also shows the average generation efficiency and the average annual hours of full load.

2014	Engines		Gas turbines	CCGTs	Steam turbines		Total
	≤ 50 kW_e	> 50 kW_e			Network-connected	Direct drive	
Fuel input [PJ]	**0.1**	**22.4**	**38.0**	**27.7**	**27.1**	**35.6**	**150.8**
Production of electricity/power [PJ]	0.0	8.9	11.7	11.4	4.5	4.3	40.7
Electrical/mechanical efficiency [%]	**23 %**	**40 %**	**31 %**	**41 %**	**16 %**	**12 %**	**27 %**
Production of heat [PJ]	*0.0*	12.1	20.6	9.9	16.5	25.3	84.5
Thermal efficiency [%]	**67 %**	**54 %**	**54 %**	**36 %**	**61 %**	**71 %**	**56 %**
Overall efficiency [%]	**90 %**	**94 %**	**85 %**	**77 %**	**78 %**	**83 %**	**83 %**
Average hours of full load [h/a]	3 778	4 411	6 574	3 938	5 829	7 894	5 096

Table 11. Overview of the production of electricity/power and heat by CHP technology (2014)

The table shows the following:

- CHP plants with engines (> 50 kW_e) achieved an overall efficiency of 94 % and an average of 4 411 hours of full load in 2015. On average, engines smaller than 50 kW_e have a lower electrical efficiency and a lower number of hours of full load than larger engines.
- In 2014 the overall efficiency of the gas turbines was 85 %. The average hours of full load totalled 6 574.
- The combined cycle gas turbines achieved an overall efficiency of 77 %. The average number of hours of full load for the CCGTs was 3 938 in 2014. That is significantly lower than in previous years (see below).
- The steam turbines have a relatively low electrical efficiency, but these plants do achieve an average overall efficiency of 78 % (network-connected steam turbines) and 83 % (direct-drive steam turbines). The average number of hours of full load for network-connected steam turbines was 5 829 in 2014. The average number of hours of full load for direct-drive steam turbines was 7 894.

The figure below illustrates the development of the production of electricity/power and heat by CHP technology type (excluding micro-CHP) and the number of equivalent hours of full load between 2005 and 2014.

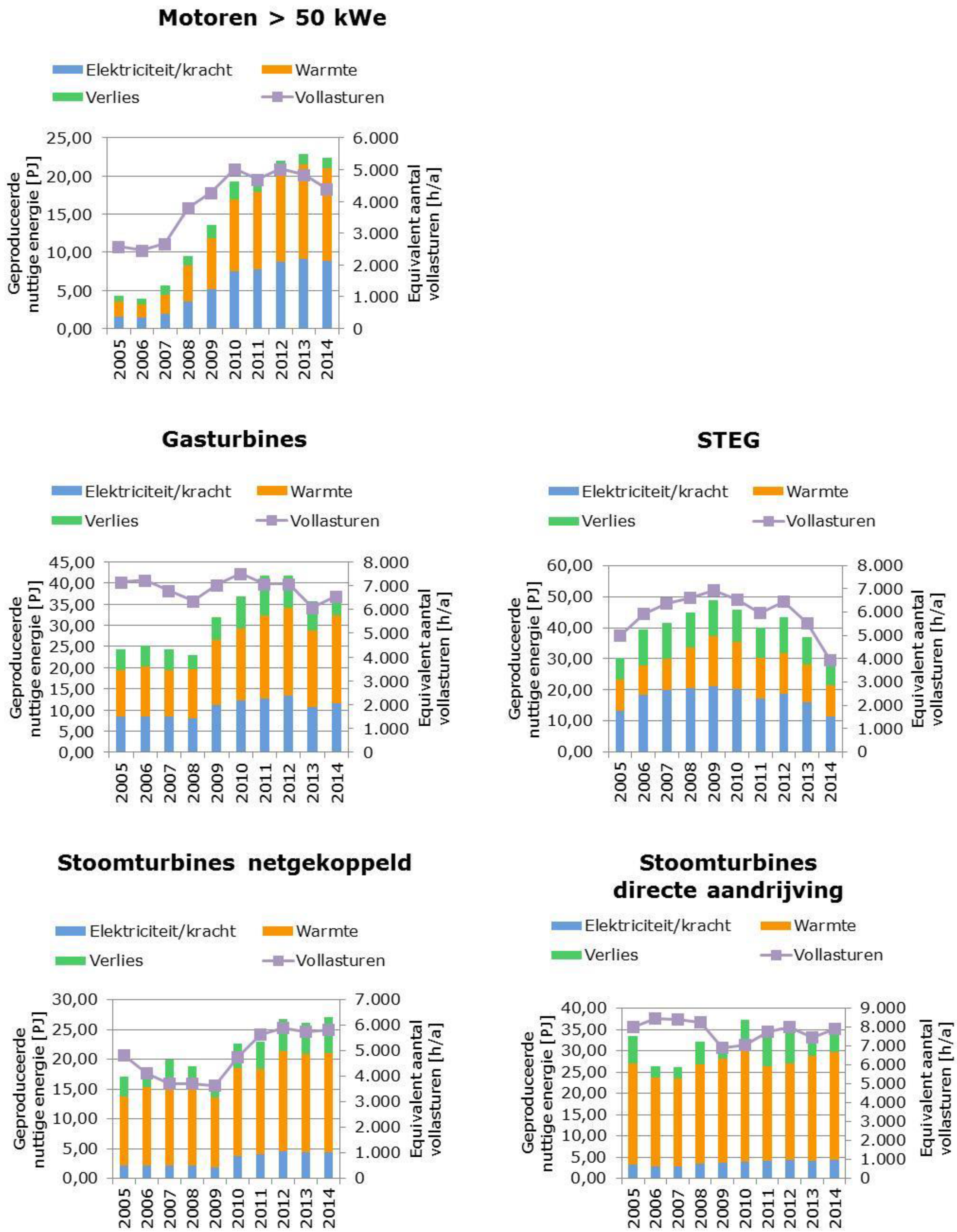


FIGURE 13: EVOLUTION OF THE PRODUCTION OF ELECTRICITY/POWER AND HEAT BY CHP TECHNOLOGY TYPE AND THE NUMBER OF EQUIVALENT HOURS OF FULL LOAD (EXCLUDING MICRO-CHP, 2005-2014)

<u>Key to figure</u>

Elekticiteit/kracht = Electricity/Power
Warmte = Heat
Verlies = Loss
Vollasturen = Hours of full load

Geproduceerde nuttige energie [PJ] = Useful energy produced [PJ]
Equivalent aantal vollasturen [h/a] = Equivalent number of hours of full load [h/a]

Motoren > 50 kW$_e$ = Engines > 50 kW$_e$
Gasturbines = Gas turbines
STEG = CCGTs
Stoomturbines netgekoppeld = Steam turbines; network-connected
Stoomturbines directe aandrijving = Steam turbines; direct drive

3.3. USEFUL RENEWABLE ENERGY PRODUCED BY CHP

A percentage of the useful energy produced by CHP plants is renewable. The percentage of renewable CHP electricity/power and CHP heat is shown in the tables below.

CHP, excluding micro-CHP	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total electricity/power produced by CHP [PJ]	33.2	35.1	37.7	43.0	47.6	46.2	49.6	44.2	40.7
Total heat produced by CHP [PJ]	57.2	59.1	66.4	74.5	84.5	79.1	85.1	83.9	84.5
Renewable CHP electricity/power [PJ]	0.5	0.6	0.7	1.2	2.6	2.9	3.4	3.6	3.8
Renewable CHP heat [PJ]	1.5	1.8	1.9	2.2	3.6	3.3	4.7	4.6	4.9
Percentage of total CHP electricity/power	**1.5 %**	**1.8 %**	**1.8 %**	**2.9 %**	**5.5 %**	**6.2 %**	**6.8 %**	**8.1 %**	**9.4 %**
Percentage of total CHP heat	**2.6 %**	**3.1 %**	**2.9 %**	**3.0 %**	**4.2 %**	**4.1 %**	**5.6 %**	**5.4 %**	**5.8 %**

Table 12. The proportion of renewable CHP electricity/power and CHP heat (excluding micro-CHP, 2006-2014)

Micro-CHP	2012	2013	2014
Total electricity/power produced by CHP [TJ]	4.0	11.6	12.9
Total heat produced by CHP [TJ]	10.5	34.9	37.9
Renewable CHP electricity/power [TJ]	1.0	7.4	7.7
Renewable CHP heat [TJ]	3.0	25.2	26.6
Percentage of total CHP electricity/power	**24.4 %**	**63.6 %**	**59.9 %**
Percentage of total CHP heat	**28.1 %**	**72.1 %**	**70.2 %**

Table 13. The proportion of renewable CHP electricity/power and CHP heat made up of micro-CHP (2012-2014)

Over the period from 2006 to 2014, renewable CHP electricity/power rose from 0.5 PJ to 3.8 PJ. Over the same period, the quantity of renewable CHP heat rose from 1.5 PJ to 4.9 PJ. The proportion of renewable CHP electricity/power was 9.4 % in 2014. The renewable share of total CHP heat was 5.8 %.

CHAPTER 4. ANALYSIS OF PRIMARY ENERGY SAVINGS AND RELATIVE PRIMARY ENERGY SAVINGS

4.1. DETERMINING THE PRIMARY ENERGY SAVINGS AND RELATIVE PRIMARY ENERGY SAVINGS

Combined heat and power plants make it possible to achieve primary energy savings compared to the separate generation of electricity and heat. The results for combined heat and power savings in this inventory are calculated on the basis of the European reference efficiencies based on the quantity of electricity from CHP pursuant to Annex II of the Energy Decree.

To determine what primary energy savings could be made by a combined heat and power plant, reference efficiencies are used. This makes it possible to carry out a comparison with the best available technology for separate production of heat and electricity in the year in which a CHP unit was built.

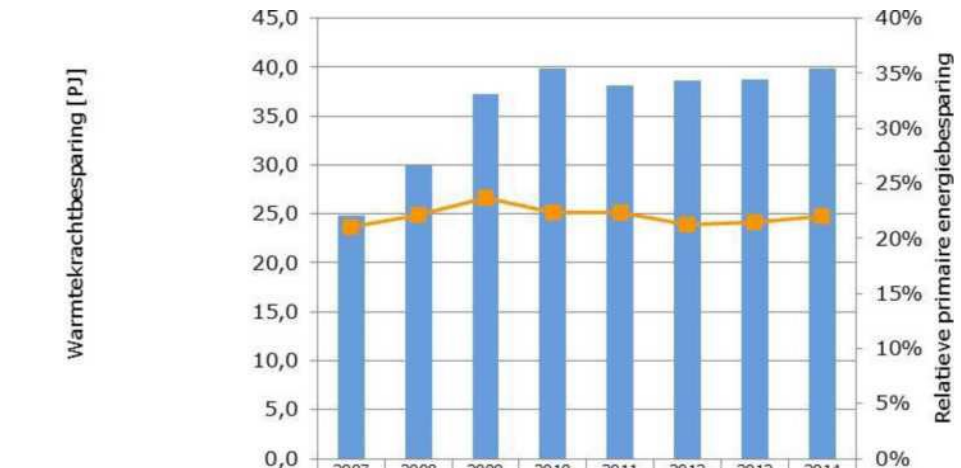
To determine the CHP savings, use is made in this inventory of the 'European' reference efficiencies as laid down in the Flemish Ministerial Decree of 1 June 2012 (*Primary energy savings based on European reference efficiencies*) (see Annex A).[6] The reference efficiencies to be used depend on the fuel used and the year of construction of the plant in question. Correction factors are also applied for avoided grid losses and deviations from the average climatic situation.

Annex A sets out the reference efficiencies for the generation of electricity and heat, the correction factors for avoided grid losses and the correction factors for the average climatic situation.

Where a CHP unit is operated with the maximum technically possible recovery of heat, the unit is said to be in full operation. In such cases, all the electricity is regarded as CHP electricity. Where this is not the case, it must be established how much electricity and heat are produced in non-CHP mode. The unit is then virtually split into a CHP part and a non-CHP part. Non-CHP electricity production takes place when no heat is being produced via the CHP process, or when part of the heat produced cannot be regarded as useful heat.

4.2. EVOLUTION OF TOTAL CHP SAVINGS

Figure 14 shows the CHP savings in Flanders over the period 2007-2014. Over the period from 2007 to 2014, total CHP savings rose from 24.8 PJ to 39.8 PJ. In 2014 the relative primary energy savings amounted to 22.0 %.



	2007	2008	2009	2010	2011	2012	2013	2014
Warmtekrachtbesparing [PJ]	24,8	29,9	37,3	39,8	38,1	38,6	38,8	39,8
Relatieve primaire energiebesparing	21,0%	22,2%	23,7%	22,4%	22,3%	21,3%	21,5%	22,0%

FIGURE 14: CHP SAVINGS BY YEAR IN FLANDERS, BASED ON EUROPEAN REFERENCE EFFICIENCIES (2007-2014)

[6] For calculating aid, the VEA uses different 'Flemish' reference efficiencies.

Key to figure
Warmtekrachtbesparing [PJ] = CHP savings [PJ]
Relatieve primaire energiebesparing = Relative primary energy savings

4.3. EVOLUTION OF CHP SAVINGS BY TYPE OF TECHNOLOGY

Total primary energy savings are shown in the tables and figure below, by type of technology. The CHP savings shown are the total sum of the CHP savings for all the individual plants.

Combined heat and power savings [PJ]	2007	2008	2009	2010	2011	2012	2013	2014
Micro-engines	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Engines (excluding micro-engines)	1.6	3.5	5.2	8.0	8.9	10.7	11.2	11.1
Gas turbines	6.1	6.8	8.6	8.1	8.6	8.8	5.7	8.3
Combined cycle gas turbines	7.5	9.2	10.7	10.8	8.4	7.7	7.7	5.9
Steam turbines; network-connected	1.9	1.8	2.5	4.3	4.2	4.5	5.8	5.6
Steam turbines; direct drive	7.6	8.6	10.3	8.7	8.1	6.9	8.2	8.8
TOTAL	**24.8**	**29.9**	**37.3**	**39.8**	**38.1**	**38.6**	**38.8**	**39.8**

Table 14. Evolution of CHP savings by type of CHP technology in Flanders, based on European reference efficiencies (2007-2014)

Relative primary energy savings	2007	2008	2009	2010	2011	2012	2013	2014
Micro-engines	-	-	-	29.1 %	26.0 %	2.4 %	29.9 %	30.3 %
Engines (excluding micro-engines)	24.4 %	27.7 %	28.7 %	31.2 %	33.1 %	34.4 %	34.0 %	34.1 %
Gas turbines	22.3 %	24.2 %	22.7 %	19.6 %	18.6 %	18.2 %	13.9 %	18.0 %
Combined cycle gas turbines	26.7 %	25.9 %	25.0 %	26.6 %	23.0 %	21.6 %	22.8 %	20.9 %
Steam turbines; network-connected	8.8 %	8.8 %	13.8 %	17.3 %	16.9 %	15.8 %	19.6 %	19.2 %
Steam turbines; direct drive	22.6 %	22.6 %	25.2 %	18.9 %	22.1 %	18.3 %	19.4 %	19.9 %
TOTAL	**21.0 %**	**22.2 %**	**23.7 %**	**22.4 %**	**22.3 %**	**21.3 %**	**21.5 %**	**22.0 %**

Table 15. Evolution of relative primary energy savings by type of CHP technology in Flanders, based on European reference efficiencies (2007-2014)

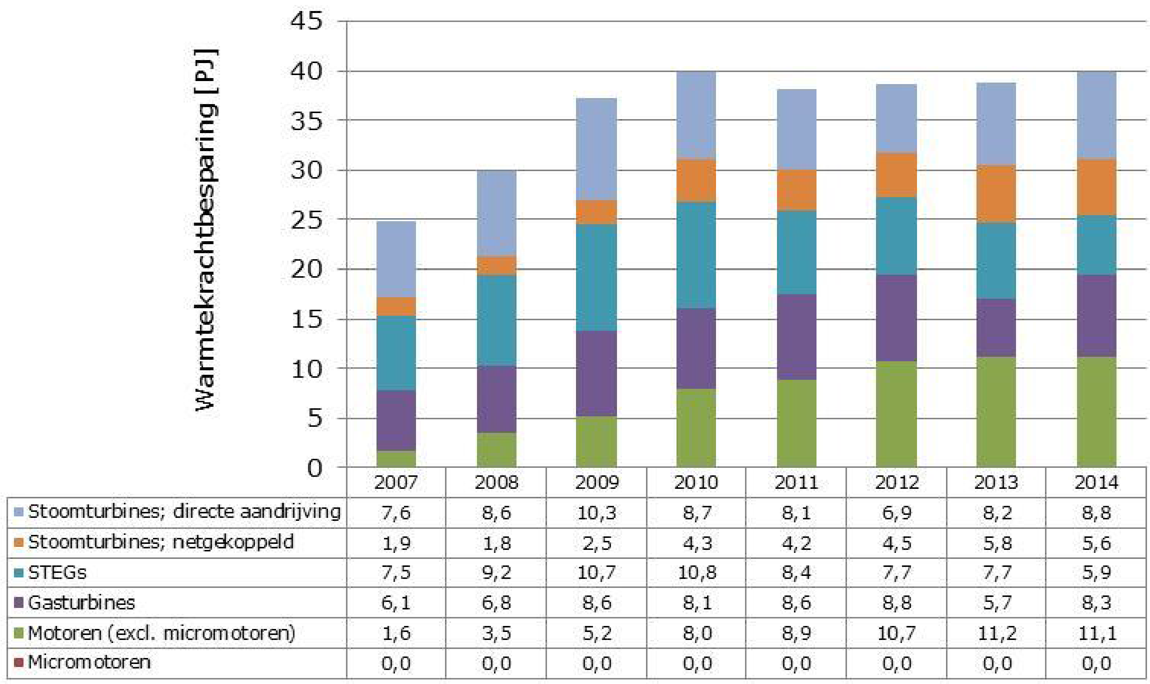


FIGURE 15: EVOLUTION OF CHP SAVINGS BY TYPE OF CHP TECHNOLOGY (2007-2014)

Key to figure
Warmtekrachtbesparing [PJ] = CHP savings [PJ]
Stoomturbines; directe aandrijving = Steam turbines; direct drive
Stoomturbines; netgekoppeld = Steam turbines; network-connected
STEGs = CCGTs
Gasturbines = Gas turbines
Motoren (excl. micromotoren) = Engines (excluding micro-engines)
Micromotoren = Micro-engines

These results indicate the following:

- Over the period from 2007 to 2014, CHP savings for engines (excluding micro-engines) rose from 1.6 PJ to 11.1 PJ. This increase reflects the considerable increase in CHP capacity with engines, a higher number of hours of full load and the improvement in the efficiency of these plants.
- In 2014 the CHP savings from gas turbines amounted to 8.3 PJ. In 2013 the CHP savings were 5.7 PJ. In 2013 a number of large plants achieved a relatively low number of hours of full load, while one plant was no longer operational. In 2014 the average number of hours of full load rose again.
- In 2014 the CHP savings from combined cycle gas turbines amounted to 5.9 PJ. The number of hours of full load and the energy produced by the combined cycle gas turbines were considerably lower in 2014 than in 2013. This explains the drop-off in primary energy savings.
- In 2014 the CHP savings from direct-drive steam turbines amounted to 8.8 PJ, while those from network-connected steam turbines totalled 5.6 PJ. The difference in primary energy savings compared to the previous year is limited.

CHAPTER 5. CONCLUSION

The key facts about CHP in Flanders in 2014 are as follows:

- The operating CHP capacity (electrical and mechanical) in Flanders in 2014 was 2 223 MW. A total of 580 CHP plants were operational, spread across 467 sites.
- The operating CHP capacity (electrical and mechanical) in Flanders rose slightly in 2014. In 2013 the capacity was 2 193 MW. The number of gas turbines, combined cycle gas turbines and steam turbines remained unchanged. The increase resulted from the growing capacity of CHP engines, especially in agriculture. The capacity of > 50 kW_e engines rose from 529 MW_e in 2013 to 560 MW_e in 2014. The number of engines (excluding micro-engines) rose from 294 to 316.
- The number of installed micro-CHP plants fell from 121 to 116. The installed capacity of micro-CHP nonetheless increased slightly from 1.01 MW_e in 2013 to 1.03 MW_e in 2014.
- The total useful output from CHP plants fell from 128.1 PJ in 2013 to 125.3 PJ in 2014. The production of CHP electricity/power fell by 8 % (from 44.2 PJ in 2013 to 40.7 PJ in 2014). This fall was mainly attributable to lower electricity production from gas-fired combined cycle power plants. The average hours of full load for combined cycle gas turbines was significantly lower in 2014 than in previous years. The percentage of CHP electricity within gross domestic electricity consumption fell from 19.9 % in 2013 to 18.4 % in 2014. Heat production in combined heat and power plants rose from 83.9 PJ in 2013 to 84.5 PJ in 2014.
- In 2014 around half of the useful energy was supplied in the form of steam (68.5 PJ). The quantity of heat produced in the form of hot water and hot air was 16.0 PJ. The production of electricity amounted to 36.4 PJ, while 4.4 PJ of power was produced.
- Total fuel consumption in 2014 was 150.8 PJ. Natural gas is the most important fuel for CHP in Flanders, making up 61 %. Gas turbines and combined cycle gas turbines were responsible for 44 % of total fuel consumption in 2014, whereas steam turbines made up 42 % and engines 15 %.
- Over the period from 2006 to 2014, renewable CHP electricity/power rose from 0.5 PJ to 3.8 PJ. Over the same period, the quantity of renewable CHP heat rose from 1.5 PJ to 4.9 PJ. The proportion of renewable CHP electricity/power was 9.4 % in 2014. The renewable share of total CHP heat was 5.8 %.
- In 2014 total CHP savings amounted to 39.8 PJ. Relative primary energy savings amounted to 22.0 %, an increase on the figures for 2013 (21.5 %).

References

[1] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

[2] Flemish Government Decree laying down general provisions in relation to energy policy, 19 November 2010.

[3] Commission Decision of 19 November 2008 establishing detailed guidelines for the implementation and application of Annex II to Directive 2004/8/EC of the European Parliament and of the Council (2008/952/EC).

[4] Commission Implementing Decision of 19 December 2011 establishing harmonised efficiency reference values for separate production of electricity and heat in application of Directive 2004/8/EC of the European Parliament and of the Council and repealing Commission Decision 2007/74/EC.

[5] Flemish Ministerial Decree laying down reference efficiencies by way of implementation of the conditions for high-quality combined heat and power plants, 1 June 2012.

[6] Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC.

Annex A: Harmonised efficiency reference values and correction factors

This annex sets out the harmonised efficiency reference values for the separate production of electricity and heat as established in the Commission Implementing Decision of 19 December 2011 in application of Directive 2004/8/EC of the European Parliament and of the Council and repealing Commission Decision 2007/74/EC. It also sets out the correction factors relating to the average climatic situation and to avoided grid losses.

A.1) Harmonised efficiency reference values for the separate production of heat

In the table below, the harmonised efficiency reference values for separate production of heat are based on net calorific value and standard atmospheric ISO conditions (15 °C ambient temperature, 1.013 bar, 60 % relative humidity).

	Type of fuel	Steam/hot water	Direct use of exhaust gases (*)
Solid	Hard coal/coke	88	80
	Lignite/lignite briquettes	86	78
	Peat/peat briquettes	86	78
	Wood-based fuels	86	78
	Agricultural biomass	80	72
	Biodegradable (municipal) waste	80	72
	Non-renewable (municipal and industrial) waste	80	72
	Oil shale	86	78
Liquid	Oils (gas oil + fuel oil), LPG	89	81
	Biofuel	89	81
	Biodegradable waste	80	72
	Non-renewable waste	80	72
Gaseous	Natural gas	90	82
	Refinery gas/hydrogen	89	81
	Biogas	70	62
	Coke oven gas, blast combustion plant gas, other waste gases, industrial waste heat	80	72

(*) Values for direct use of exhaust gases should be used if the temperature is 250 °C or higher.

A.2) Correction factors relating to the average climatic situation

Correction factors relating to the average climatic situation and method for establishing climate zones for the application of the harmonised efficiency reference values for separate production of electricity (referred to in Article 3(1))

(a) Correction factors relating to the average climatic situation

Ambient temperature correction is based on the difference between the annual average temperature in a Member State and standard atmospheric ISO conditions (15 °C).

The correction will be as follows:

(i) 0.1 %-point efficiency loss for every degree above 15 °C;

(ii) 0.1 %-point efficiency gain for every degree below 15 °C;

Example:

When the average annual temperature in a Member State is 10 °C, the reference value of a cogeneration unit in that Member State has to be increased by 0.5 %-points.

(b) Method for establishing climate zones

The borders of each climate zone will be constituted by isotherms (in full degrees Celsius) of the annual average ambient temperature which differ by at least 4 °C. The temperature difference between the average annual ambient temperatures applied in adjacent climate zones will be at least 4 °C.

Example:

In a given Member State, the average annual ambient temperature is 12 °C at location A and 6 °C at location B. The difference is greater than 5 °C. The Member State then has the option to introduce two climate zones, separated by an isotherm of 9 °C, thereby defining one climate zone between the isotherms of 9 °C and 13 °C, with an average annual ambient temperature of 11 °C, and a second climate zone between the isotherms of 5 °C and 9 °C, with an average annual ambient temperature of 7 °C.

The table below shows the annual average temperature used to determine the correction factor for the ambient temperature (a). The method for establishing climate zones (b) has not been applied.

	2007	2008	2009	2010	2011	2012	2013	2014
Average temperature (°C)	11.5	10.9	11.0	9.7	11.6	10.6	10.1	11.9

Table 16. Average annual temperature (2007-2014). Source: Royal Meteorological Institute of Belgium (RMI), www.meteo.be

A.3) Harmonised efficiency reference values for the separate production of electricity

In the table below, the harmonised efficiency reference values for separate production of electricity are based on net calorific value and standard atmospheric ISO conditions (15 °C ambient temperature, 1.013 bar, 60 % relative humidity).

	Year of construction Type of fuel	2001 and before	2002	2003	2004	2005	2006-2011	2012-2015
Solid	Hard coal/coke	42.7	43.1	43.5	43.8	44.0	44.2	44.2
	Lignite/lignite briquettes	40.3	40.7	41.1	41.4	41.6	41.8	41.8
	Peat/peat briquettes	38.1	38.4	38.6	38.8	38.9	39.0	39.0
	Wood-based fuels	30.4	31.1	31.7	32.2	32.6	33.0	33.0
	Agricultural biomass	23.1	23.5	24.0	24.4	24.7	25.0	25.0
	Biodegradable (municipal) waste	23.1	23.5	24.0	24.4	24.7	25.0	25.0
	Non-renewable (municipal and industrial) waste	23.1	23.5	24.0	24.4	24.7	25.0	25.0
	Oil shale	38.9	38.9	38.9	38.9	38.9	39.0	39.0
Liquid	Oils (gas oil + fuel oil), LPG	42.7	43.1	43.5	43.8	44.0	44.2	44.2
	Biofuels	42.7	43.1	43.5	43.8	44.0	44.2	44.2
	Biodegradable waste	23.1	23.5	24.0	24.4	24.7	25.0	25.0
	Non-renewable waste	23.1	23.5	24.0	24.4	24.7	25.0	25.0
Gaseous	Natural gas	51.7	51.9	52.1	52.3	52.4	52.5	52.5
	Refinery gas/hydrogen	42.7	43.1	43.5	43.8	44.0	44.2	44.2
	Biogas	40.1	40.6	41.0	41.4	41.7	42.0	42.0
	Coke oven gas, blast combustion plant gas, other waste gases, industrial waste heat	35	35	35	35	35	35	35

A.4) Correction factors for avoided grid losses

Correction factors for avoided grid losses for the application of the harmonised efficiency reference values for separate production of electricity (referred to in Article 3(2))

Voltage	For off-site electricity	For on-site electricity
> 200 kV	1	0.985
100-200 kV	0.985	0.965
50-100 kV	0.965	0.945
0.4-50 kV	0.945	0.925
< 0.4 kV	0.925	0,860