About the potential for the application of high-efficiency co-generation based on useful heat demand in Hungary (including high-efficiency micro-cogeneration)

(report in accordance with Article 10(1) of the Directive 2004/8/EC of the European Parliament and of the Council, containing the elements listed in Article 6(1))

October 2009

Introduction

Combined heat and electricity generation (hereinafter referred to as 'cogeneration') is desirable to be established at locations where cogeneration can be used to satisfy existing or actual new heat demand. When assessing the potential for the further application of cogeneration, it is recommended to start with reviewing heat demand, and then assess the portion which may be satisfied by the existing co-generation capacities as well as the cases when new plants are needed. In certain cases, existing plants may need to be replaced. This means that there are at least three routes for the growth of cogeneration:

- better utilisation of the unused capacities of existing systems, e.g. by introducing new heat consumers;
- extension and modernisation of existing plants;
- installation of new plants, and potentially the addition of new sites.

We have reviewed the changes in heat demand and in cogeneration in two large fields based on available data. One of these fields was the production sector (industrial producers); the other was the field of public services.

A summary of the changes in the main figures of cogeneration between 2004 and 2007 is presented in Table 1.

Table 1

		2004		2005		2006		2007	
Number of units in operation:		figure	%	figure	%	figure	%	figure	%
Public services	pcs	194	69.78	214	64.46	347	90.84	341	88.57
Industrial producers	pcs	84	30.22	118	35.54	35	9.16	44	11.43
Total:		**278**	**100,00**	**332**	**100,00**	**382**	**100,00**	**385**	**100,00**
Installed electric cogeneration capacity:									
Public services	MW	1 584	89.27	1 657	88.54	1 839	93.08	2 088	93.35
Industrial producers	MW	190	10.73	215	11.46	137	6.92	149	6.65
Total:		**1 775**	**100,00**	**1 872**	**100,00**	**1 976**	**100,00**	**2 237**	**100,00**
Installed thermal cogeneration capacity:									
Public services	MW	3 775	80.41	3 440	82.04	3 743	85.61	3 955	88.74
Industrial producers	MW	920	19.59	753	17.96	629	14.39	502	11.26
Total:		**4 694**	**100,00**	**4 193**	**100,00**	**4 373**	**100,00**	**4 457**	**100,00**
Heat use:									
Public services	TJ	**35829**	**60.17**	**38471**	**61.31**	**36029**	**61.19**	**34698**	**61.57**
Industrial producers	TJ	**23710**	**39.82**	**24273**	**38.69**	**22852**	**38.81**	**21660**	**38.43**
Total:		**59539**	**100,00**	**62744**	**100,00**	**58881**	**100,00**	**56358**	**100,00**

From Table 1 it is apparent that in the period under review, cogeneration shifted towards public services in terms of the number of cogeneration plants in operation and the installed electric and thermal capacities. There is a significant dominance of public services in the field of heat use, with a share in excess of 60%.

1. Changes in heat demand by sectors in Hungary between 2004 and 2007

Industrial sectors can be divided into two groups. One contains the sectors where cogeneration plants were also used in the period under review, while the other contains those where they were not used.

1.1. Study of the purchased heat demand in the sectors where cogeneration plants were used between 2004 and 2007

Table 2 presents how the amount of purchased heat used by the individual sectors changed over time between 2004 and 2007. Tables 3 to 9 detail the trends relevant to cogeneration in the individual sectors.

Table 2

Use of purchased heat energy from 2004 to 2007	2004	2005	2006	2007	2007/2004
	TJ	**TJ**	**TJ**	**TJ**	
Chemical industry	6 723	7 813	8 663	8 567	1.27
Production of non-ferrous mineral products	344	244	295	326	0.95
Food, drink and tobacco production	1 110	938	918	940	0.85
Paper production, editorial and printing act.	1 859	1 936	1 537	1 155	0.62
Metal products, plant and equipment	3 486	3 749	3 731	3 423	0.98
Processing industry not otherwise classified	88	60	76	49	0.56
Transportation, post and telecommunication	523	196	717	n.a.	1.37*
Total	**14 133**	**14 936**	**15 937**	**14 460**	**1.02**

* Note: 2006/2004

Chemical industry

Table 3 presents the trends relevant to cogeneration in the chemical industry.

Table 3

Chemical industry		**2004**	**2005**	**2006**	**2007**	**2007 / 2004**
Number of units in operation	pcs	4	3	4	5	**1.250**
Installed electric cogeneration ca-	MW	49	13	15	13	**0.261**
Electricity produced	GWh	134	40	59	70	**0.520**
Electricity produced	TJ	482	143	213	251	**0.520**
Installed thermal cogeneration ca-	MW	358	113	100	35	**0.096**
Heat energy produced	TJ	3 086	1 951	1 880	1 893	**0.614**

Heat energy purchased	TJ	6 723	7 813	8 663	8 567	**1.274**
Heat energy production and pur-	TJ	9 809	9 764	10543	10 460	**1.066**

Although there was a slight increase in the number of installed cogeneration plants in the sector, the installed electric and heat capacity of the plants decreased significantly. The amount of electricity and heat energy produced was nearly halved, while there was hardly any change in the sum of heat energy produced and heat energy purchased. The loss of own production was made up by purchasing.

Production of non-ferrous mineral products

Table 4 presents the trends relevant to cogeneration in this sector.

Table 4

Production of non-ferrous mineral products		**2004**	**2005**	**2006**	**2007**	**2007 / 2004**
Number of units in operation	pcs	4	0	0	0	**0.000**
Installed electric cogeneration ca-	MW	10	0	0	0	**0.000**
Electricity produced	GWh	10	0	0	0	**0.000**
Electricity produced	TJ	36	0	0	0	**0.000**
Installed thermal cogeneration ca-	MW	51	0	0	0	**0.000**
Heat energy produced	TJ	15	0	0	0	**0.000**
Heat energy purchased	TJ	344	244	295	326	**0.947**
Heat energy production and pur-	TJ	359	244	295	326	**0.908**

By the end of the period, cogeneration had been discontinued in the sector. Discontinued heat production was set off by the purchasing of heat. Even though the sum of heat energy produced and heat energy purchased was lower at the end of the period than at the beginning, an increase in heat demand could be observed over the last years.

Food, drink and tobacco industry

Table 5 presents the trends relevant to cogeneration in this sector.

Table 5

Food, drink and tobacco industry		**2004**	**2005**	**2006**	**2007**	**2007 / 2004**
Number of units in operation	pcs	8	10	11	12	**1.500**
Installed electric cogeneration ca-	MW	65	71	80	84	**1.291**

Electricity produced	GWh	204	206	186	173	**0.846**
Electricity produced	TJ	734	740	670	621	**0.846**
Installed thermal cogeneration ca-	MW	393	426	428	352	**0.895**
Heat energy produced	TJ	3 521	3 886	3 163	3 140	**0.892**
Heat energy purchased	TJ	1 110	938	918	940	**0.847**
Heat energy production and pur-	TJ	4 631	4 824	4 081	4 081	**0.881**

Both the number of cogeneration plants and their installed electric capacity increased, while the installed thermal capacity decreased. It seems likely that the increase in the number of cogeneration plants was the result of replacing some of the plants - e.g. replacing back-pressure gas turbines with gas engines.

Paper and printing industry

Table 6 presents the detailed changes in the paper and printing industry.

Table 6

Paper and printing industry		**2004**	**2005**	**2006**	**2007**	**2007 / 2004**
Number of units in operation	pcs	2	3	2	3	**1.500**
Installed electric cogeneration ca-	MW	14	16	16	16	**1.190**
Electricity produced	GWh	59	59	51	49	**0.824**
Electricity produced	TJ	212	214	182	175	**0.824**
Installed thermal cogeneration ca-	MW	53	72	72	68	**1.277**
Heat energy produced	TJ	1 780	1 575	1 316	1 474	**0.828**
Heat energy purchased	TJ	1 859	1 936	1 537	1 155	**0.621**
Heat energy production and pur-	TJ	3 639	3 511	2 853	2 629	**0.722**

There was a slight increase in the number of operating cogeneration plants as well as in the amount of installed electric and thermal capacity over the period under review. Total heat demand decreased, with a significant drop in the amount of purchased heat.

Manufacturing of metal products, plant and machinery

Table 7 presents the trends relevant to cogeneration in this sector.

Table 7

Metal products, plant and machinery		**2004**	**2005**	**2006**	**2007**	**2007 / 2004**

Number of units in operation	pcs	1	0	2	6	**6.000**
Installed electric cogeneration ca-	MW	0.4	0.0	8.1	12.5	**31.629**
Electricity produced	GWh	2	0	51	95	**47.584**
Electricity produced	TJ	7	0	185	340	**47.584**
Installed thermal cogeneration ca-	MW	0.5	0.0	7.8	14.9	**27.594**
Heat energy produced	TJ	9	0	194	333	**35.959**
Heat energy purchased	TJ	3 486	3 749	3 731	3 423	**0.982**
Heat energy production and pur-	TJ	3 495	3 749	3 925	3 756	**1.074**

There was a spectacular increase in the number of operating cogeneration plants as well as their installed electric and thermal capacity in this industrial sector. As a result, own heat production increased significantly; nevertheless, it still meets only a small portion of total heat demand.

Industrial sectors not otherwise classified

Table 8 presents the trend relevant to cogeneration in the industrial sectors not otherwise classified.

Table 8

Industrial sectors not otherwise classified		**2004**	**2005**	**2006**	**2007**	**2007 / 2004**
Number of units in operation	pcs	3	6	7	10	**3.333**
Installed electric cogeneration ca-	MW	3.2	2.2	11.9	20.4	**6.393**
Electricity produced	GWh	10	33	33	114	**11.617**
Electricity produced	TJ	35	120	118	410	**11.617**
Installed thermal cogeneration ca-	MW	3.4	7.0	14.5	29.2	**8.473**
Heat energy produced	TJ	59	160	235	314	**5.331**
Heat energy purchased	TJ	88	60	76	49	**0.560**
Heat energy production and pur-	TJ	147	220	311	363	**2.472**

This category comprises various industrial sectors. The figures indicate that there was a spectacular increase in the number of operating cogeneration plants as well as the installed electric and thermal capacity. The amount of heat produced increased significantly, while the amount of heat energy purchased was nearly halved.

Transportation, post and telecommunication

Table 9 presents the trends relevant to cogeneration in this industry.

Table 9

Transportation, post and telecommunication		2004	2005	2006	2007	2007 / 2004
Number of units in operation	pcs	62	96	9	8	**0.129**
Installed electric cogeneration ca-	MW	49.1	112.1	5.2	2.3	**0.047**
Electricity produced	GWh	259	445	23	9	**0.034**
Electricity produced	TJ	931	1 602	82	32	**0.034**
Installed thermal cogeneration ca-	MW	60.7	136.1	7.2	3.7	**0.061**
Heat energy produced	TJ	1 107	1 765	127	45	**0.041**
Heat energy purchased	TJ	523	196	717	n.a.	**0.000**
Heat energy production and pur-	TJ	1 630	1 961	844	45	**0.028**

In this blanket category there was a drastic drop in both the number of operating cogenerating plants and in the amount of installed electric and thermal capacity. The drop in capacities was also reflected in the amount of thermal and electric energy produced.

1.2. Study of the purchased heat demand in the sectors where cogeneration plants were not used between 2004 and 2007

Table 10 presents the purchased heat use in the sectors where cogeneration plants were not used

Table 10

Use of purchased heat energy in the period from 2004 to 2007 [TJ]	2004	2005	2006	2007	2007/2004
Textile and textile product manufacturing	251	134	103	61	0.24
Leather, leather product, footwear manu-	23	24	21	20	0.88
Wood processing	16	40	20	0	0.00
Coke production, petroleum processing	4 800	5 059	4 619	3 916	0.82
Vehicle manufacturing	738	532	433	366	0.50
Water management	79	43	42	69	0.87
Construction industry	105	116	100	100	0.95
Agriculture	14	10	8	n.a.	

From Table 10 it is apparent that the amount of heat purchased decreased over the reviewed period in every sector where no cogeneration plants were used. Sectors may be divided into three categories based on the extent of the reduction.

a. There was a large-scale reduction (100%-75%) in wood processing and textile product manufacturing.
b. There was a medium-scaled reduction (75%-25%) in vehicle manufacturing and agriculture.
c. There was a slight reduction (25%-0%) in the manufacturing of leather goods, in mineral oil processing, water management and construction industry.

With the exception of mineral oil production, the demand for purchased heat is so low or has decreased so much that there seems to be no justification for installing cogeneration plants.

Mineral oil production requires a lot of heat, and this demand has only decreased slightly over the period; what is more, heat demand is concentrated. The heat used in the mineral oil processing industry, however, is from cogeneration.

2. Study of the heat demand of public services in 2004 to 2007

The largest area – demanding purchased heat – of public services is district heating. Table 11 presents the changes in installed capacities in the field of public services from 2004 to 2007.

Table 11

Public services		**2004**	**2005**	**2006**	**2007**	**2007/2004**
Number of units in operation	[pcs]	194	214	347	341	1.76
Installed electric cogeneration capacity	[MW]	1 584	1 657	1 839	2 088	1.32
Installed thermal cogeneration capacity	[MW]	3 775	3 440	3 743	3 955	1.05

From table 11 it is apparent that the increase in installed electric capacities was significantly larger than the increase in installed thermal capacities. Over the recent years, gas engine plants of several hundred MW have been put into operation.

2.1. Cogenerated energy in district heating

The justification and precondition for cogeneration is appropriate heat demand; therefore one of the largest and most permanent fields of cogeneration domestically is the field of public district heating

services. Table 12 presents the changes in heat sold in the heat provision sector over the reviewed period.

Table 12

Heat sold on the system level in the heat supply sector, 2004 - 2007						
	Year	2004	2005	2006	2007	2007/2004
Total heat sold	TJ	52 333	51 394	47 745	44 835	0.86
Residential heat demand	TJ	28 188	29 440	27 787	25 995	0.92
Heat produced by gas engines	TJ	3102	5977	6675	8798	2.84
Deviation from the average temperature in the heating season	°C	+0.50	-0.49	+0.51	+1.84	

The drop in heat demand was the result of a reduction and/or discontinuation of industrial heat demand on one hand, and of a reduction in residential heat demand on the other hand.

The drop in residential heat demand is rooted in the following factors:

- increased energy prices cause the population to use heat more economically;
- doors and windows have been replaced, external heat insulation has been applied, heating systems have been modernized and made controllable in many buildings in order to reduce the heat loss of homes;
- the annual average temperature has increased, causing a reduction in the heat demand for heating;
- some smaller district heating systems have been closed down, and the affected homes switched to gas-based heating.

Further increase of the installed capacity of cogeneration plants in the district heating sector is influenced by three factors:

- it was apparent from Table 12 that both industrial and residential heat demands in the heat market for district heating service providers tended to decrease;
- the decisive majority of heat production already takes place in cogeneration plants; the heat demand which is not currently being met from cogeneration could partially be satisfied by better utilisation of the current plants;
- the installed capacity of cogeneration plants, especially gas engines, has increased significantly over the last years.

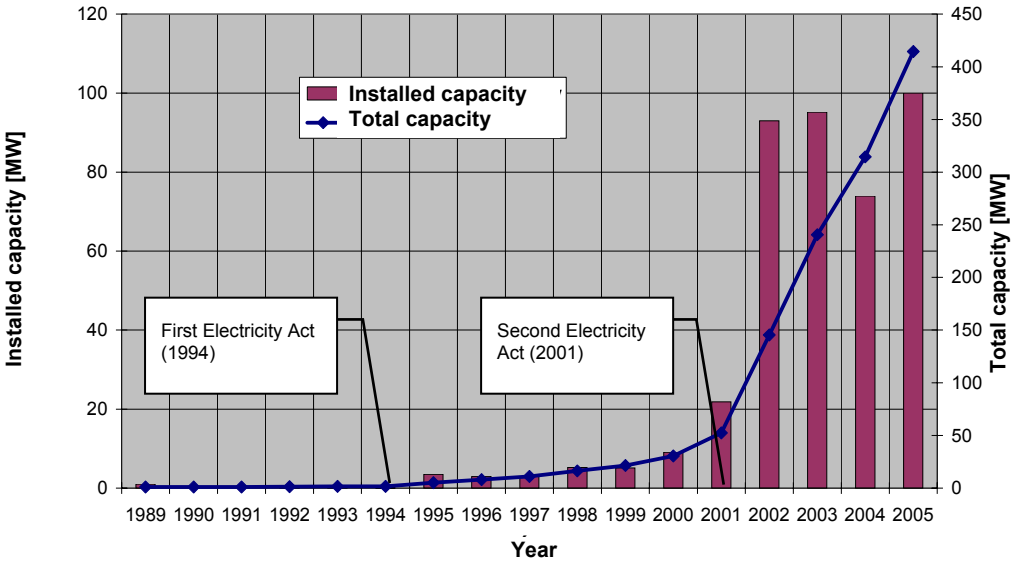
This leads us to conclude that due to the factors presented above, the growth of installed cogeneration capacities will slow down.

The total amount of heat sold in the framework of district heating services in 2003 was 57,688 TJ, of which 67% was heat combined with power generation. The corresponding figure in 2000 was only 57%. The increase was partly due to the installation of combined cycle blocks to replace earlier smaller units, leading to a higher portion of cogenerated heat in large power plants, and also to the installation of gas engines in heating plants which had no cogenerated electricity production before.

Diagram 1 presents the annual installed capacity and total capacity of gas engine plants in the period from 1989 to 2005. It is apparent from the diagram that growth started after the Act of 1994 on electricity entered into force; then, after the introduction of the Act of 2001 on electricity, a highly dynamic growth of about 90 MW/year was seen in the electric capacities of gas engines.

Diagram 1

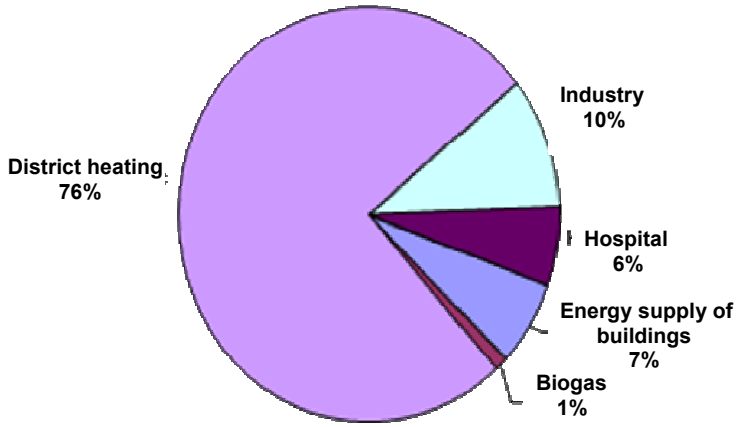
Growth of cogenerated electric capacities of gas engines from 1989 to 2005



Utilisation of gas engine electric capacities by field of application is presented in Table 2.

Diagram 2

Utilisation of gas engine electric capacities by field of application



Analysis of the fields of application shows that 76% of all installed capacity – i.e. over 310 MW electric capacity – is installed in the district heating systems. This is because district heating services are highly widespread in Hungary.

There has also been some growth in the cogeneration capacities based on small-capacity gas turbines, but both the extent and dynamics of this growth was far behind that of gas engines. The reason why small-scale gas turbine plants spread more slowly over the last 15 years is that the main field of application for small-capacity units is district heating, especially small and medium scale district heating systems; in this field however – in the range of a few ten MWs of electric capacity – gas engines offer clear economic advantage due to their higher electric efficiency at a specific output.

2.2. Cogenerated electricity in other public services

Data in Table 13 show that there was a clear increase in the amount of heat sold in the communal sector in the period from 2004 to 2007.

Table 13

Amount of purchased heat [TJ]	2004	2005	2006	2007	2007/2004
Communal and other consumers	7 641	9 031	8 242	8 703	1.14

The heat demand of communal and other consumers is already being met by cogeneration or purchased from cogeneration plants. There still exist various heat demands in the field of the energy supply of buildings which are satisfied from traditional sources.

3. Changes in the installed capacity, heat and electricity production as well as hours of utilisation of cogeneration plants in the period from 2004 to 2007

Table 14 presents the changes in the installed capacity, heat and electricity production as well as the power to heat ratio (σ) of the cogeneration plants operating in Hungary in the period under review.

Table 14

Aggregated data of cogeneration plants						
Aggregated data		**2004**	**2005**	**2006**	**2007**	**2007/2004**
Total installed electric capacity	[MW]	1 775	1 872	1 975	2 237	1.26
Total installed thermal capacity	[MW]	4 694	4 193	4 373	4 457	0.95
Total electricity production	[GWh]	6 055	7 004	8 020	8 568	1.42
Total electricity production	[TJ]	21 797	25 216	28 871	30 846	1.42
Total heat energy production	[TJ]	47 199	47 970	46 880	49 222	1.04
σ		0.46	0.53	0.62	0.63	1.36

It is interesting to see in Table 14 that while the installed electric cogeneration capacities increased by 26% and the amount of electricity produced increased by 42% in the reviewed period, the installed thermal cogeneration capacities decreased by 5% and the amount of heat from cogeneration increased by 4% - i.e. it stagnated. The power to heat ratio (σ) increased by 36%.

We can conclude that in the newly installed cogeneration units, the share of electricity generation is increasing while heat production is stagnating.

The improvement in the power to heat ratio over the last few years is related to the technological advancement and transformation of cogeneration plants. At the beginning of district heating, this ratio was 0.2 for back-pressure gas turbines in Budapest; after the initial parameters of steam turbines were raised, it increased to 0.45. For combined cycle gas and steam turbines, the corresponding value is 0.95, and it is 0.75 for the internal combustion engine (gas engine). There are currently several combined cycle plants (gas and steam turbines) with a high power to heat ratio (Kispesti Erőmű, Újpesti Erőmű, Kelenföldi Erőmű, Csepeli Áramtermelő Erőmű, Nyíregyházi Kombinált Ciklusú Erőmű, Debreceni Kombinált Ciklusú Erőmű, Miskolci Kombinált Ciklusú Erőmű, MVM Észak-Buda Kombinált Ciklusú Erőmű), some of which were put into operation during the period indicated. The power to heat ratio was also improved as a result of the installation of gas engines with a capacity of several hundred MW.

Improvement of the power to heat ratio has been the result of technological modernisation and has not involved a reduction in the ratio of useful heat.

Tables 15 and 16 present the heat production operating hours of the cogeneration plants in the period under review.

Table 15

Operating hours of cogeneration plants with an efficiency over 75% [h]				
By type	**2 004**	**2 005**	**2 006**	**2 007**
Combined cycle plant **(efficiency>=80%)**	3 788	5 536	6 605	6 579
Gas turbine with heat exchanger	3 221	4 325	2 743	3 173
Internal combustion engine	4 814	5 127	4 605	5 387
Steam: back-pressure turbine	2 501	2 139	2 160	2 250
Steam: extraction-type turbine (efficiency>=80%)	n.a.	4 156	2 570	2 868

Table 16

Operating hours of cogeneration plants with an efficiency under 75% [h]				
By type	**2 004**	**2 005**	**2 006**	**2 007**
Combined cycle plant **(efficiency<80%)**	2 920	3 707	4 450	3 764
Gas turbine with heat exchanger	3 525	n.a.	6 533	1 572
Internal combustion engine	3 544	4 083	2 049	2 305
Steam: back-pressure turbine	2 953	2 324	5 527	2 763
Steam: extraction-type turbine (efficiency < 80%)	1 487	1 737	1 789	2 171

Analysis of the installed capacities, the amount of heat produced and the annual hours of operation figures shows that the hours of operation figure of the cogeneration plants currently in operation is

- low if efficiency is <75%,
- is much higher if efficiency >= 75%, which is

advantageous in terms of the use of primary fuel.

The introduction of **micro units** (cogeneration plants of less than 50 kVA) is made possible in all respects by the regulations: neither their installation nor their operation is subject to an authorisation.

The law provides for the mandatory off-take of electricity generated by micro units. There are currently a few tens of such plants in operation. Industry is not yet prepared for the manufacturing and distribution of micro units, which have therefore not spread among the population or small and medium enterprises; a significant increase in their numbers is expected in 3-5 years.

4. Summary

Heat use in Hungary has slightly decreased over the recent years. Heat use by industrial sectors – which makes up nearly 40% of all heat use – has decreased along with the transformation of industrial production; no significant changes are expected in the coming years.

A significant portion of heat demand is associated with public services, especially district heating services; the relevant heat use makes up over 60% of all heat use. Heat use associated with district heating has stagnated or slightly decreased, which was primarily due to better heat utilisation (heat insulation of homes, spreading of metering and control etc.).

As for the trends in heat demands, 65-70% of the heat demand of district heating is co-generated along with electricity, in increasingly efficient and modern plants. Consequently, the growth rate of cogeneration will decrease in the future.
The number and installed capacity of cogeneration pants is expected to increase in the following applications:

- newly built housing estates;
- shopping centres;
- newly built office blocks;
- warehouses, logistics centres;
- universities, colleges, hospitals.

Cogeneration is based predominantly on natural gas at the moment and in the near future, but already an appreciable percentage belongs to renewable energy sources, and this figure is expected to increase gradually.

(Statistical data were provided by Energia Központ Nonprofit Kft.)