Legislative Motivation for Implementation of

Combined Heat and Power: The Most Successful Energy Projects in Hungary*

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ABSTRACT

Cogeneration is a very important tool for saving primary energy, avoiding network losses, and reducing emissions, in particular of greenhouse gases. In addition, efficient use of energy by cogeneration can contribute positively to the security of a nation's energy supply and to the competitive situation in both the private and public sectors of the energy market. For this reason, the Hungarian Ministry for Economy and Transport enacted legislative motivations for the implementation of combined heat and power (CHP). As a result of this legislation, power grid administrators have been obliged since January 2003 to purchase, at a subsidized price, electricity produced by cogeneration plants. The legislation of the Ministry heavily influenced energy investment, and implementation of CHP units with gas engines, which were the most successful energy projects in Hungary in the last few years.

This article:
- introduces the Ministry mandate to purchase cogenerated electricity at a subsidized price
- shows the influence of the mandate on investments
- reviews changes, reasons, and market reactions chronologically from instatement of the mandate
- shows the results of an economic analysis of a selected project.

*This research was supported by the Hungarian National Science Foundation (OTKA) project T046339.

CHP SUPPORT SCHEME IN HUNGARY

The obligatory purchasing and subsidization of the price of electricity generated in combined heat and power (CHP) plants with nominal electricity output between 100 kWh and 50 MWh has been in effect since January 2003 [1].

The purchase of cogenerated electricity is required if the electricity is generated in expansion turbines or in CHP plants based on municipal waste, geothermal, solar, wind, biomass, biogas, or hydroelectric energy sources.

Figure 1 shows the difference throughout an average winter day between the subsidized price of electricity from cogeneration sources and the wholesale price of electricity in the year 2006.

Table 1 shows the subsidized price of CHP electricity generated during the period of February 1, 2003 through July 17, 2004. The data shown takes into consideration CHP plants where nominal electricity output is under 6 MW or where output is under 50 MW, the energy source is natural gas, and waste heat is supplied to the district heating (DH) system. The price change is affected by the change in gas prices. The peak and off-peak periods (central European time) are shown in Table 2.

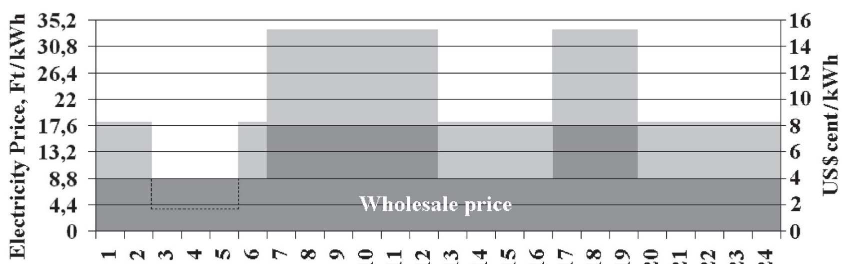

Figure 1. The wholesale price of electricity and subsidized price of cogenerated electricity* [2].

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*Excluding direct taxes:

— The rate of the value-added tax (VAT) from among the direct taxes, starting from 1/1/2006 is 20%.

— The rate of the so-called Energy Tax, introduced on 1/1/2004 is 186 HUF/Mwh (84.55 US$cent/Mwh) and is also subject to VAT. (The Energy Tax shall not be paid by residential customers.)

Saturday and Sunday are out peak periods (

Table 1. Price of electricity generated in CHP [2]

HUF/kWh (US$cent*/kWh)	February 1, 2003	October 5, 2003	January 1, 2004
In peak period	20.85 (9.48)	21.75 (9.89)	21.90 (9.96)
Out of peak period	13.05 (5.93)	13.60 (6.18)	13.70 (6.23)

* 1 US$ = 220 HUF (Hungarian Forint)

Table 2. The peak and out of peak periods

Part of the day		Summer	Winter
Peak period	Daily	08-14	07-13
	Evening	18-21	17-20
Out of peak period	Night	21-08	20-07
	Daily	14-18	13-17

Saturday and Sunday are out of peak periods (24h/d)

The required purchase of cogenerated electricity from plants where nominal output was between 100 kW and 50 MW and the yearly average efficiency was higher than 65% was in effect until July 17, 2004. In the case of cogeneration plants using gas engines, the monthly average efficiency needed to be higher than 75%. An electricity producer needed to state at the beginning of the year that its average efficiency would meet the requirements set forth by the Ministry's legislation. There were no further requirements for a plant to become a subsidized producer.

THE RESULT OF THE OBLIGATORY PURCHASING OF COGENERATED ELECTRICITY

The order of the Ministry significantly influenced energy investment, making implementations of CHP units with gas engines the most numerous new energy projects in Hungary in the past few years. Figure 2 shows the increase in the cumulative nominal power output of cogeneration gas engines that resulted from the Ministry's subsidization.

The total demand and production of electricity in all of Hungary are shown in Figure 3 for an average winter weekday. As can be seen from these figures, demand for electricity drops in the early morning

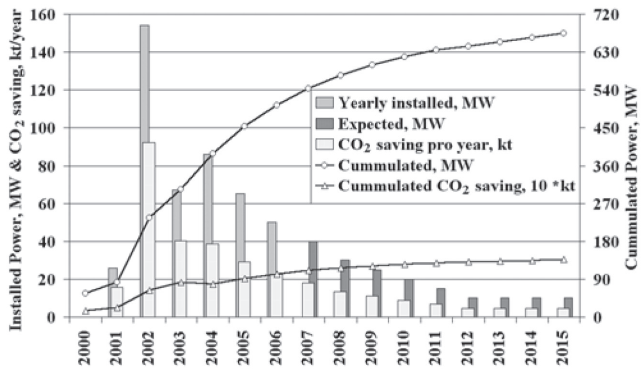

Figure 2. Sum of cogeneration units with gas engine, yearly installed in Hungary

hours. As a result of the required purchase of cogenerated power, and free-market forces, nuclear power stations should decreased their output during the early morning period.

To rectify this situation where the output of nuclear power plants varied, the Ministry of Economy and Transport established a new variable subsidized price schedule, where the subsidized price of cogenerated electricity varied over the course of the day for an additional period between 3 a.m. and 6 a.m. The new rate schedule was set so that the average price of subsidized electricity did not change,

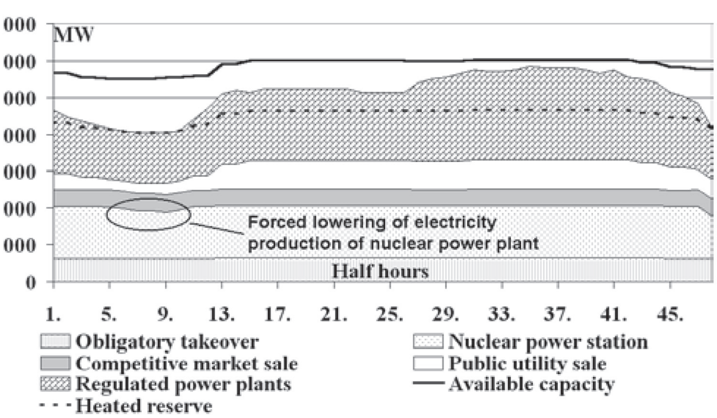

Figure 3. Electricity demand and supply at wintertime work day in Hungary in year 2003. [3]

but during the so called deep valley period, the subsidized electricity price was set lower than the price of the fuel burned in the CHP plants' gas engines. The revised price structure, effective since July 17, 2004, is shown in Table 3.

These changes to the price schedule of subsidized electricity had the desired results. After the changes took effect, one half of CHP plant owners decreased their electrical power output during the deep valley period, when their fuel cost was greater than their income, and the other half shut down their engines for those three hours. These changes allowed large nuclear power stations to maintain a constant electrical load around the clock.

Figure 4 shows electricity produced in cogeneration plants today and that expected to be produced in the future.

Comparing the average electricity price at the free market rate (10

Table 3. Feed-in price of electricity generated in CHP after establishing the deep valley period [2]

HUF/kWh (US$cent/kWh)	July 17, 2004	February 1, 2005	January 18, 2006
In peak period	25.40 (11.55)	27.54 (12.52)	33.62 (15.28)
Out of peak period	13.70 (6.23)	14.85 (6.75)	18.14 (8.25)
Deep valley period	3.00 (1.36)	3.00 (1.36)	3.00 (1.36)

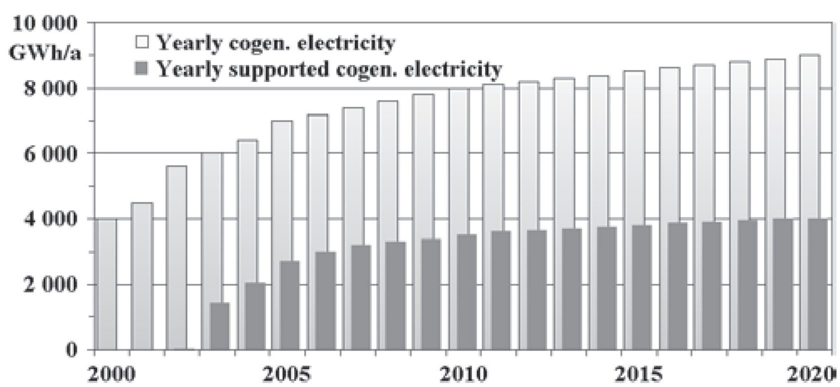

Figure 4. The electricity, generated in cogeneration nowadays and as expected in the future [4]

to 12 HUF/kWh) with the subsidized price of cogenerated power, one can conclude that total subsidies paid by the state on CHP electricity are significant. Figure 5 shows the total paid in electricity subsidies by the Hungarian government, in billions of HUF, in previous years and as projected for the year 2005. With these subsidies it is possible to influence energy investment and decrease environmental pollution, but unfortunately it costs about 0.60 HUF/kWh for each consumer.

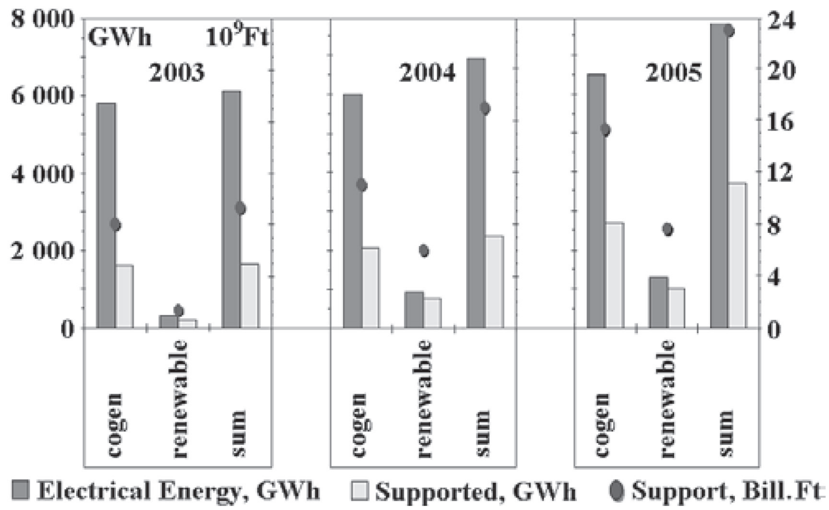

Figure 5. Electricity produced by cogeneration and subsidies paid [4]

ECONOMICAL ANALYSIS OF A COGENERATION UNIT PROJECT

A CHP gas engine was installed in a hospital, and the economics of the installation was analyzed. In a hospital, heat consumers include the swimming pool, thermal baths, domestic hot water system, and indoor heating systems. The swimming pool requires 40 kW to maintain the temperature of the water during the day. At night, water is purged from the swimming pool and replaced with fresh water, and 220 kW are required to sufficiently reheat the pool. The heat load of the thermal baths is 25 kW throughout the day. The heat requirement for domestic hot water, needed for showering, kitchen use, etc., is 170 to 360 kW, depending on demand. Heat demand at the dimensioning outdoor temperature of -13°C is 1,794 kW today, but in the near future will be 3,595 kW. In Figure 6, the heat demands of 1,900 and 3,800 kW correspond to an outdoor temperature of -15°C. These figures are valid when designed cooling demand is 360 kW.

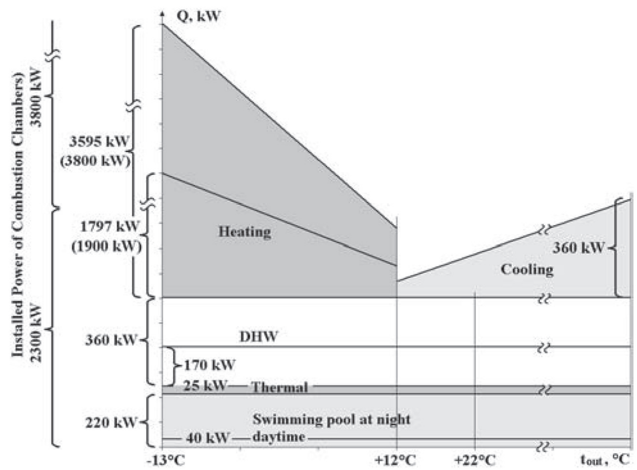

Figure 6. Heat demand versus outdoor temperature

Pre-existing heating sources at the hospital in question consisted of two hot water boilers with nominal heat outputs of 2,300 kW and 3,500 kW. Cooling at the hospital is done by compression chillers. The total heating and cooling demand of the hospital depends on the outdoor temperature, as shown in Figure 6.

A heat duration diagram showing the expected heat demand, shown in Figure 7, was constructed based on long-term outdoor temperature data collected between the years 1900 and 2000. The diagram shows the total yearly heat demands of each heat consumer in a hospital. The heat demand of the swimming pool has two totals: one for the daytime and another for the night.

On the diagram is also shown the expected yearly total heat consumption of hospital heat users. Expected energy consumption for indoor heating was calculated for an indoor temperature of +22 °C and an outdoor temperature of -15°C. The figure of 16,720 GJ demanded for indoor heating per year was calculated based on records of gas consumption of the hospital's boilers and an assumption of 88% average heat supply efficiency (90 % boiler efficiency and 2% losses in boiler house). Total yearly expected heat consumption will be 25,000 to 45,000 GJ, depending on the addition or expansion of consumers. The

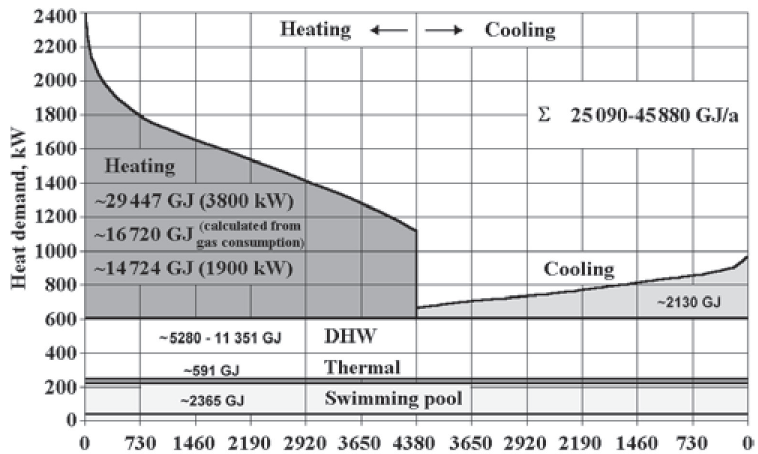

Figure 7. Heat duration diagram

expected heat requirement for absorption cooling is about 2,130 GJ per year. Analyzing the heat duration diagram, one can conclude that a gas engine for cogeneration with ~ 1 MWt nominal heat output would be suitable for use with this system.

An investor assessed the business potential of cogeneration at the hospital and decided to install a CHP unit to supply heat to the hospital. The investor entered a 10-year heat supply contract with the hospital and a long-term contract with the utility company to purchase electricity.

The nominal data of the selected gas engine are:

- Electric power output 1,064 kW
- Thermal output 1,157 kW (+/- 8%)
- Natural gas consumption 274 gNm^3/h
- Exhaust gas temperature 427 °C
- Exhaust gas flow rate (wet) 4,495 gNm^3/h
- Exhaust gas mass flow rate (wet) 5,680 kg/h
- Exhaust gas flow rate (dry) 3,986 gNm^3/h
- Exhaust gas mass flow rate (wet) 5,259 kg/h
- Cooling water flow rate 49.7 m^3/h
- Cooling water temperature 95/75 °C

Emissions:

- NO_x ≤ 500 mg/Nm^3
- CO ≤ 650 mg/Nm^3

There are two sources for heat output from the gas engine: the cooling system of the engine and exhaust gasses. Heat ex-changers for the engine cooling system and exhaust gasses are connected in series. The engine cooling system uses a pump that circulates water through the system at a constant volumetric flow rate. The connection of the cooling system to the heat supply system is shown in Figure 8.

Nominal parameters of the compression chiller are:
- Cooling output 250 kW
- Cooling medium (water): 7/12 ºC
- Hot water temperatures 95/75 ºC
- Hot water mass flow 15 400 kg/h

The heat utilized from the gas engine is shown in Figure 9 as a portion of total heat demand.

Because the electricity price during the early morning deep valley period is lower than the cost of natural gas, operation of the gas engine is effective only 21 hours daily. For this reason, the total thermal output

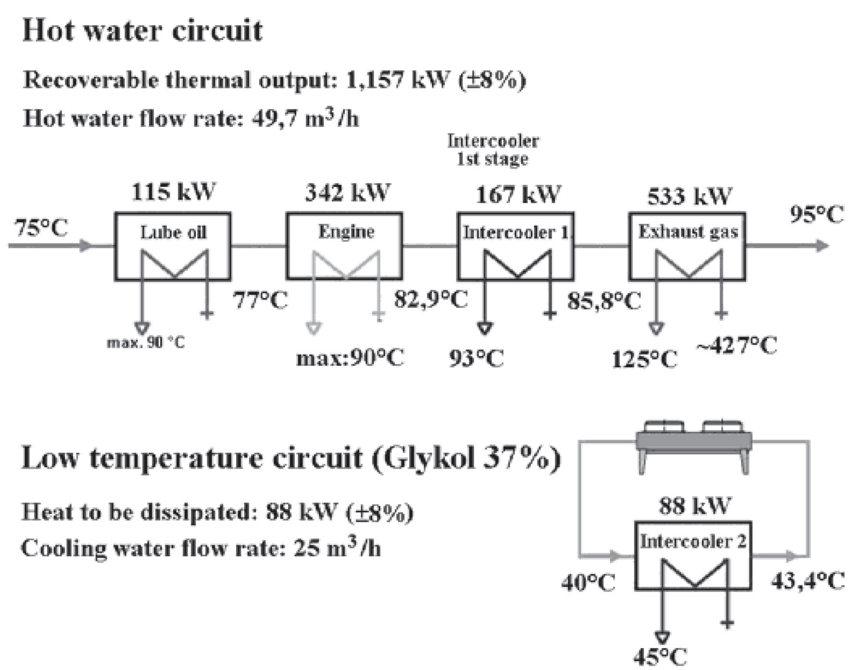

Figure 8. Connection of cooling system

shown in Figure 9 is not the nominal thermal output of the gas engine, 1,157 kW, but instead its 21/24 output, 1,012 kW. One month yearly of standby is calculated into this figure for maintenance of the engine. The utilized heat from the gas engine will be 15,963 GJ per year. The heat utilization of 14,686 GJ/yr, also shown on Figure 9, is 8% less.

Heat consumption for the summer was calculated based on the data shown in Table 4.

The economic impact of this project is similar to the two district heating CHP investment projects, summarized in Table 5 and Table 6.

SUMMARY

This article showed that with legislative measures it is possible to influence energy investments. Obligatory purchasing and price subsidization of electricity generated in CHP plants caused the installed power

Table 4. Heat consumption calculation for the summer

Heat demand, kW_t		h/day	h	kWh_t	GJ
Swimming	45	12	2190	82,125	296
pool	220	6	1095	200,750	723
Thermal b.	25	18	3285	68,436	246
DHW	360	18	3285	985,500	3,548
Cooling	334	18	3285	914,325	3,292
Total:	**939**			2,251,136	**8,104**

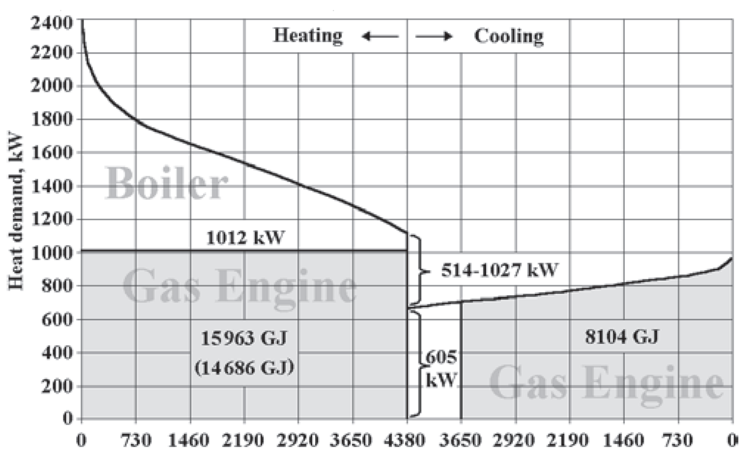

Figure 9. Heat, utilized from gas engine, with respect to the heat duration diagram of the hospital.

Table 5. The economic impact of the installation of CHP units in a district heating system with two gas engines.

2 GAS ENGINES, kUS$	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total sales revenue	0	2 308	2 444	2 670	2 793	2 904	3 010	3 120	3 212	3 298	3 386	3 477
Total operating expenses	0	1 526	1 645	1 944	2 035	2 117	2 195	2 277	2 345	2 409	2 474	2 542
EBITDA	0	782	799	726	758	787	814	843	867	889	912	935
Depreciation	0	264	264	264	264	264	264	264	264	264	264	264
EBIT (operating profit)	0	518	535	462	494	523	551	579	603	625	648	671
Interest recived	0	0	0	0	0	0	0	0	0	0	0	0
Interest paid	98	521	445	310	227	145	104	63	21	0	0	0
Net financial profit	98	521	445	310	227	145	104	63	21	0	0	0
Profit before taxation	-98	-3	91	152	267	378	447	517	582	625	648	671
Tax to be paid	-16	0	15	24	43	60	71	83	93	100	104	107
Profit after taxation	-82	-2	76	128	225	317	375	434	489	525	544	564
Dividend	0	0	0	0	0	0	0	0	0	0	0	0
Net profit	-82	-2	76	128	225	317	375	434	489	525	544	564

Table 6. The economic impact of the installation of CHP units in a district heating system with three gas engines.

3 GAS ENGINES, kUS$	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total sales revenue	0	3 981	4 216	4 582	4 796	4 992	5 177	5 368	5 507	5 636	5 768	5 904
Total operating expenses	0	2 487	2 675	3 134	3 283	3 415	3 543	3 676	3 787	3 891	3 999	4 109
EBITDA	0	1 494	1 541	1 448	1 513	1 577	1 634	1 692	1 720	1 744	1 769	1 795
Depreciation	0	341	341	341	341	341	341	341	341	341	341	341
EBIT (operating profit)	0	1 153	1 200	1 107	1 172	1 236	1 293	1 351	1 379	1 404	1 428	1 454
Interest recived	0	0	0	0	0	0	0	0	0	0	0	0
Interest paid	163	674	586	425	323	212	154	93	31	0	0	0
Net financial profit	163	674	586	425	323	212	154	93	31	0	0	0
Profit before taxation	-163	479	614	682	850	1 025	1 139	1 258	1 348	1 404	1 428	1 454
Tax to be paid	-26	77	98	109	136	164	182	201	216	225	229	233
Profit after taxation	-137	403	516	573	714	861	956	1 056	1 132	1 179	1 200	1 221
Dividend	0	0	0	0	0	0	0	0	0	0	0	0
Net profit	-137	403	516	573	714	861	956	1 056	1 132	1 179	1 200	1 221

capacity of CHP plants in Hungary to in-crease by almost 500 MW in the last five years. CHP units were established as heat sources in district heating systems, in hospitals and other communal buildings. Installing CHP units in district heating systems was significant because in 96 Hungarian cities, more than 640,000 flats are heated by district heating, about 200,000 of those in the capital, Budapest. The heat consumption of district-heated public buildings, including schools, hospitals, and other public buildings, is over 50 PJ/yr. These investments in CHP plants caused a significant reduction in greenhouse gas emissions.

This article also pointed out mistakes in the formulation of the Ministry decree. The influence of the obligatory purchasing of CHP electricity was not fully analyzed before the measure passed. As a result, the establishment of CHP units influenced the electricity production of other, already established power plants, and the decree therefore had to be changed one and a half years after it took effect.

The article also showed an example of the influence of legislative measures on CHP installations, demonstrating that similar decrees can be passed to motivate the implementation of power generation from renewable energy sources in the future. The les-son learned from this decree is that the broader influence of future measures should be more carefully analyzed before their implementation.

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ABOUT THE AUTHOR

Albin Zsebik, Ph.D., studied at the Czech Technical University, Prague (1968-70) and at the Technical University of Budapest (1970-74), and prepared his MSc thesis at the Moscow Energy Institute (1974). In 1982, Albin Zsebik received his Ph.D. in energy engineering from the Hungarian Academy of Sciences.

He worked at the Research Institute for Energy in Bratislava, Czechoslovakia (1974-77) as a technical expert, at the Technical University of Budapest, Hungary as a research fellow (1977-81) and at the Research Institute for Energy at Bratislava, Czechoslovakia as a senior technical expert (1981-83). Since 1983, he has been employed at the Budapest University of Technology and Economics, Hungary, lectured on district heating systems (heat generation, cogeneration, transmission, distribution, and consumption), and on systems and control engineering.

Dr. Zsebik is CEO and manager of the Energy Consulting Company "JOMUTI Kft." (1990-present), editor-in-chief, of the professional journal *Energiagazdálkodás* (*Energy Management*) ISSN 002—0757 (2001-present) secretary general, Scientific Society of Energy Economics, (2001-present), assistant director, International Member Development for Central & Eastern Europe, Association of Energy Engineers (AEE), Atlanta GA, USA, (2004-present). Dr. Zsebik was elected into the AEE Hall of Fame in 2004.