*Implementation of CHP Plants: The Best Investment Possibilities 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 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, and because of Hungary's electricity price structure, companies with large electricity and heat consumption, or with the possibility to sell electricity or heat, are considering the technical and economical benefits of implementing local combined heat and power (CHP) plants to supply energy for their technology processes.

This article introduces the Hungarian electricity price structure, and shows the results of a feasibility study for implementation of a CHP plant.

THE ELECTRICITY PRICE STRUCTURE

Table 1 shows the electricity price structure in the case under consideration. One can see that the wholesale (energy) price is ~60% of the total energy price. The rather large percentage of supplemental costs is for the system operator, local distributor and the intermediary company (IC) motivated consideration of a local CHP plant. The target of the

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

plant's nominal electricity output was to satisfy existing and anticipated electricity demand of the process. Because the neighboring company has high steam demand, (120 – 170 tons/hr), the feasibility study assumed that the steam produced in parallel with electricity would be sold for their technical processes.

THE ELECTRICITY DEMAND

Considering the current 10-12 MWe continuous electricity capacity needs, the signed letter of intent to implement the next power generation unit (~8.7 MWe), the intention to build up some reserves, and the eventual sale of electricity for IC, three base scenarios of CHP plants were analyzed.

- Option 1 P = 2 x 6 = 12 MW_e
- Option 2 P = 3 x 6 = 18 MW_e
- Option 3 P = 4 x 6 = 24 MW_e

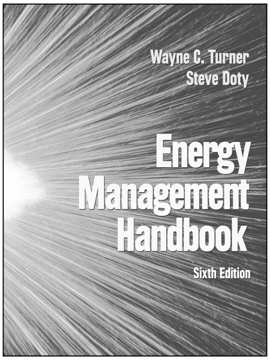
The price of the gas turbine-generator sets with ~6 MW_e nominal electric capacity were calculated based on the price offers received.

Table 1. The electricity price structure in the considered case* [2]

		HUF/kWh	US$/MWh	% in Total
Energy Trader	Energy Price	13.00	68.42	60.76
System Operation public	System Operation Charge	3.12	16.41	14.57
	System Service Charge	0.67	3.54	3.14
	Transmission Charge	1.07	5.65	5.02
Local Distributor	Distribution Charge	0.80	4.21	3.74
Intermediary Company (IC)	IC Transmission and Line Cost	1.40	7.37	6.54
	IC Profit & Other Costs	1.33	7.01	6.22
Sum Total without VAT		**21.39**	**112.6**	

* Excluding direct taxes

- The rate of the value added tax (VAT) from among the direct taxes since 1/1/2006 is 20%.
- The rate of the Energy Tax, introduced on 1/1/2004 is 186 HUF/MWh (84.55 US$cent/MWh)
- Using 190 HUF/US$ exchange ratio



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THE CONCEPTUAL SCHEME OF THE CHP PLANT

The electricity demand reviewed above and the opportunity of selling the heat favors electricity production by gas turbine with a heat recovery steam boiler. The schematic of a 6 MW_e nominal output unit can be seen in Figure 1. The 1st option analyzed is built up from two similar units, the 2nd option from three, and the 3rd from four.

It is practical to connect the unit's electricity output to the 6 kV electric network at the nearest transformer, and the steam output to the steam network of the IC at the nearest appropriate point to the CHP plant. For the individual units a common condensate collector and make-up water system (boiler feed water and TW storage tank) were considered.

PLANT OPERATION OPTIONS

While developing the plant operation options, it was assumed that the electricity generators run under equal operating conditions at nominal performance. The difference between the three options is their nominal output only. Table 2 shows the energy production, assuming 8,400 hr/year operation at nominal output. (Gas turbine output is influenced somewhat by weather, but in the economic analysis, nominal performance appears adequately precise.)

ECONOMIC ANALYSIS

The first costs of the analyzed options were:
1 US$ = 190 HUF (Hungarian forint)

- Option 1—2,530 MHUF (13.32 MUS$)
- Option 2—3,580 MHUF (18.84 MUS$)
- Option 3—4,650 MHUF (24.47 MUS$)

Division of the energy costs arising in CHP plants into fixed and variable costs has its benefits. Fixed costs can be predicted based on investments and annual fixed cost. Variable costs are connected to fuel consumption and maintenance costs, depending on operating time.

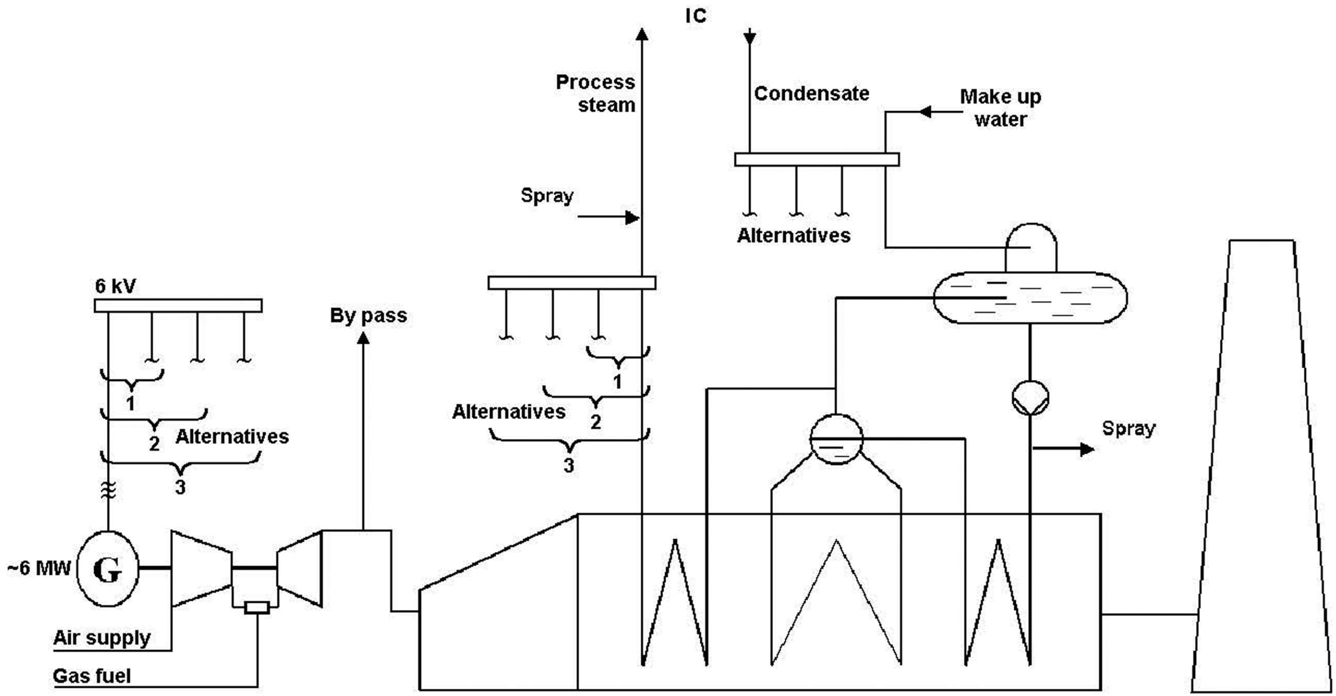

Figure 1. Simplified schematic of planned CHP generation by gas turbine

Table 2. Main energy production data

Assumed operating time 8,400 hr/year		**1st option 2 x 6 = 12 MW_e**	**2nd option 3 x 6 = 18 MW_e**	**3rd option 4 x 6 = 24 MW_e**
Annual electricity production	MWh	100,800	151,200	201,600
Annual natural gas use	GJ	1,036,800	1,555,200	2,073,600
Annual natural gas use	kNm3	30,494	45,741	60,988
Efficiency of the electricity generation	%	35	35	35
Exhaust flow	kg/s	41.8	62.7	83.5
Exhaust temperature	°C	532	532	532
Annual steam production (32 barg, 340°C)	ton/yr	463,680	695,520	927,360

Figure 2 shows the composition of the annual fixed cost of different options.

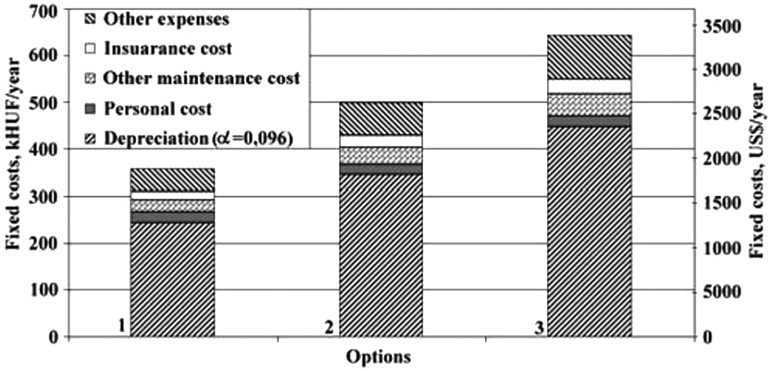

Figure 2. Composition of annual fixed cost

Figure 3 shows the composition of the variable costs.

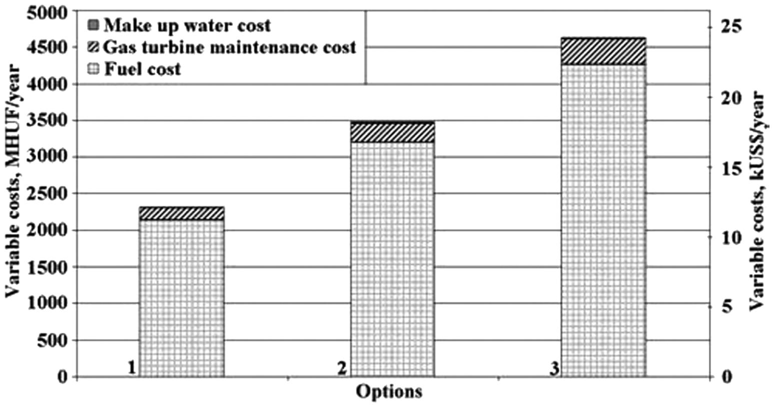

Figure 3. Composition of annual variable costs

The economic analysis was done by two methods, in each case with sensitivity analysis.

1. In the first case with yearly fixed and variable cost and the assumed heat cost, the specific cost of electricity was calculated.
2. Next the dynamic models for 10 years economic life and 15 years technical life were analyzed for the economic results of investment.

It was assumed, that by August 2007, the decision to implement would be made, and the 1st option can be put in operation at the beginning of July 2009.

SPECIFIC COST OF ELECTRICITY

The specific cost of electricity was calculated assuming different prices for steam. Table 3 shows the specific costs of electricity generated in the CHP plant, if the assumed steam price is equal to the existing natural gas price of 1,882 HUF/GJ (9.91 US$/GJ), resp. lower by 10% 1,694 Ft/GJ (8.92 US$/GJ) resp. 20% 1,506 Ft/GJ (7.93 US$/GJ).

Table 4 shows the specific costs of electricity generated in the CHP plant if the investment cost varies by ± 20%.

Table 5 shows the specific costs of electricity generated in the CHP plant, if not only the steam price, but the natural gas price is varied by ± 20% from the base price 1,882 HUF/GJ (9.91 US$/GJ).

SPECIFIC COST OF STEAM GENERATION

The specific cost of steam was calculated assuming different electricity prices. Table 6 shows the specific costs of steam generated in the CHP plant, if the assumed electricity price is equal to the existing electricity base price, 21,394 HUF/MWh (112.6 US$/MWh) resp. lower by 10% 19,255 HUF/MWh (101.34 US$/MWh) resp. 20% 17,329 HUF/MWh (91.21 US$/MWh)

PAYBACK PERIOD, NPV AND IRR

Based on the first costs, the simple payback period, and internal rate-of-return (IRR) were calculated. The simple payback period for Option 1, depending on the electricity and natural gas prices, is ~5 - 10 years. A realistic payback period is 6.7 years. For other options, it is a bit lower. With 15 years of operation, the internal rates-of-return of the estimated options are in the range of 29 to 33%. The net present values (NPV) of investments in the considered options, for 15 years of operation, and discount rates of 8%, are summarized in Table 7.

Table 3. Specific cost of electricity generated in CHP

Steam Price (US$/GJ)	**Option 1**	**Option 2**	**Option 3**
	Specific electricity cost, US$/MWh		
9.91	94.16	92.87	92.29
8.92	98.72	97.42	96.84
7.93	103.27	101.97	101.39

Table 4. Specific cost of electricity generated in CHP

First Cost	**Option 1**	**Option 2**	**Option 3**
	Specific electricity cost, US$/MWh		
Base -20%	90.89	89.79	89.28
Base -10%	92.53	91.33	90.79
Base Case	94.16	92.87	92.29
Base +10%	95.79	94.42	93.79
Base +20%	97.43	95.96	95.29

Table 5. Specific cost of electricity generated in CHP

NG and steam price	Option 1	Option 2	Option 3
	Specific electricity cost, US$/MWh		
Base -20%	80.56	79.27	78.68
Base -10%	87.36	86.07	85.49
Base Case	94.16	92.87	92.29
Base +10%	100.96	99.67	99.09
Base +20%	107.77	106.48	105.89

Table 6. Specific cost of steam generation

Electricity Price (US$/MWh)	Option 1	Option 2	Option 3
	Specific electricity cost, US$/MWh		
112.60	5.89	5.62	5.49
101.34	8.34	8.06	7.94
91.21	10.55	10.27	10.14

Table 7. Net Present Value for 15 years of operation

		Option 1	Option 2	Option 3
Investment	MHUF	1,898	2,087	2,277
	1000 US$	9,987	10,986	11,984
NPV at 8%	MHUF	2,033	3,240	4,354
	1000 US$	10,702	17,052	22,915

Table 8. Escalation factors

Years	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Inflation, CPI (%)		4.50	3.50	2.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
CPI Index	1.000	1.045	1.082	1.109	1.131	1.153	1.176	1.200	1.224	1.248	1.273	1.299	1.325
Natural Gas Price Change (%)		4.50	3.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Natural Gas Price Index	1.000	1.045	1.082	1.114	1.147	1.182	1.217	1.254	1.291	1.330	1.370	1.411	1.454
Electricity Price Change (%)		4.50	3.50	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Electricity Price Index	1.000	1.045	1.082	1.114	1.147	1.182	1.217	1.254	1.291	1.330	1.370	1.411	1.454

FINANCIAL ANALYSIS OF INFLATION

The implementation of the project was also considered with inflation. Table 8 shows the inflation rate, estimated natural gas and electricity price changes, and indices over the next few years.

It was assumed that the financing of the CHP plant will be 25% from the owner's sources and 75% from a loan. The loan was fixed at the annual 4.5% EURIBOR, to which was added 1.85% MARGE. The cost of credit was calculated as 1%.

It was assumed that in the case of Option 1, 30% of the investments cost will be made in 2008 and the rest in 2009. In the second half of 2009, the plant will operate. Payment will begin in 2010.

The economic impacts of the project for a 15-year analysis period are summarized in Table 9 and Table 10. Figure 4 shows the change of the debt to service ratio coverage (DSCR) for the base case of the investments resp. natural gas and steam price with the varying electricity price (-10 and -20%).

SUMMARY

This article shows that the implementation of CHP units in the plant under consideration could assure economic benefit for an investor.

The simple payback period for Option 1, depending on the electricity and natural gas prices, is ~5 - 10 years. The realistic payback period is 6.7 years. The payback periods for other options are a bit lower. With 15 years of operation, the IRR is in the range of 29 to 33%.

The net present value of investment for 15 years of operation and 8% discount rate of Option 1 is ~4,513 MHUF (~23.75 MUS$).

The results show that the liability index in the assumed 10 years repayment period with the right reserve is above the required 1.2 even if the base data change in the range of ±10-20%.

In addition to the economic benefits, implementation of the CHP plant could significantly reduce in greenhouse gas emissions.

References

[1] Decree of the Ministry of Economy and Transport No. 56/2002. (29. XII.) GKM on the rule and price of electricity, subject to compulsory takeover, issued in Magyar Közlöny.

Table 9. The economic impact of the Option 1

P&L statement, kUS$	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total sales revenue	0	8 622	22 202	32 015	37 686	38 817	39 981	41 181	42 416	43 685	44 999	46 349	47 740	49 172	50 647	52 166	40 299
Total operating expenses	0	7 110	18 056	25 614	29 975	30 840	31 730	32 646	33 589	34 560	35 559	36 587	37 645	38 735	39 856	41 010	31 963
EBITDA	0	1 512	4 145	6 401	7 711	7 977	8 251	8 534	8 827	9 125	9 440	9 762	10 094	10 437	10 791	11 157	8 336
Depreciation	0	0	918	1 377	1 836	1 836	1 836	1 836	1 836	1 836	1 836	1 836	1 377	0	0	0	0
EBIT (operating profit)	0	1 512	3 228	5 024	5 876	6 141	6 416	6 699	6 991	7 293	7 605	7 927	8 718	10 437	10 791	11 157	8 336
Interest paid	0	0	918	1 377	1 836	1 836	1 836	1 836	1 836	1 836	1 836	1 836	1 377	0	0	0	0
Net financial profit	222	745	963	1 064	962	845	729	612	495	379	262	146	44	0	0	0	0
Profit before taxation	-222	767	2 265	3 961	4 914	5 296	5 687	6 087	6 496	6 914	7 343	7 781	8 674	10 437	10 791	11 157	8 336
Tax to be paid	0	123	362	634	786	847	910	974	1 039	1 106	1 175	1 245	1 388	1 670	1 727	1 785	1 334
Profit after taxation	-222	644	1 902	3 327	4 128	4 449	4 777	5 113	5 457	5 808	6 168	6 536	7 286	8 767	9 065	9 372	7 002
Dividend	0																
Net profit	-222	644	1 902	3 327	4 128	4 449	4 777	5 113	5 457	5 808	6 168	6 536	7 286	8 767	9 065	9 372	7 002

Table 10. The economic impact of the installation of the Option 3

P&L statement, kUS$	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total sales revenue	0	8 623	17 764	18 297	18 846	19 411	19 994	20 594	21 211	21 848	22 503	23 178	23 874	24 590	25 328	26 087	13 435
Total operating expenses	0	6 924	14 255	14 665	15 088	15 522	15 969	16 430	16 903	17 391	17 893	18 409	18 940	19 487	20 050	20 630	10 611
EBITDA	0	1 699	3 509	3 632	3 758	3 889	4 024	4 164	4 308	4 457	4 611	4 769	4 933	5 102	5 277	5 457	2 824
Depreciation	0	0	999	999	999	999	999	999	999	999	999	999	0	0	0	0	0
EBIT (operating profit)	0	1 699	2 510	2 633	2 760	2 891	3 026	3 165	3 309	3 458	3 612	3 771	4 933	5 102	5 277	5 457	2 824
Interest paid	0	0	999	999	999	999	999	999	999	999	999	999	9 987	0	0	0	0
Net financial profit	190	634	602	539	476	412	349	285	222	159	95	32	0	0	0	0	0
Profit before taxation	-190	1 065	1 908	2 094	2 284	2 478	2 677	2 880	3 087	3 300	3 517	3 739	4 933	5 102	5 277	5 457	2 824
Tax to be paid	0	170	305	335	365	397	428	461	494	528	563	598	789	816	844	873	452
Profit after taxation	-190	895	1 603	1 759	1 919	2 082	2 249	2 419	2 593	2 772	2 954	3 141	4 144	4 286	4 433	4 584	2 372
Dividend	0																
Net profit	-190	895	1 603	1 759	1 919	2 082	2 249	2 419	2 593	2 772	2 954	3 141	4 144	4 286	4 433	4 584	2 372

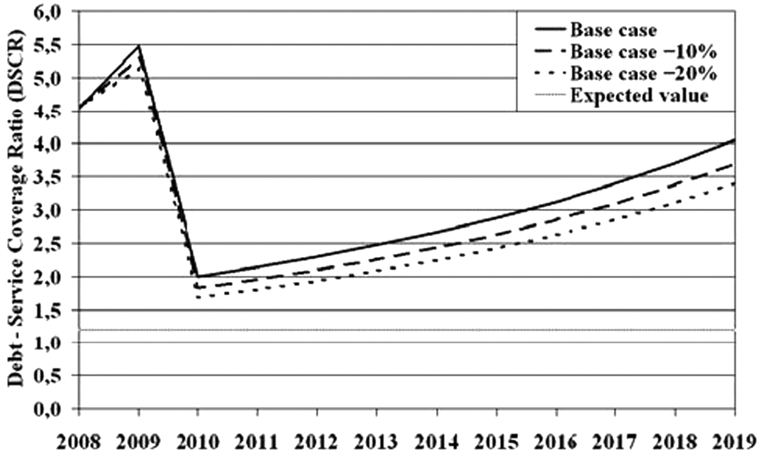

Figure 4. Change of the DSCR

[2] www.eh.gov.hu – Home Page of the Hungarian Energy Office.
[3] Feasibility study for implementation of CHP unit in a chemical plant

ABOUT THE AUTHOR

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

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