CO-GENERATION – INCREASING ENERGY EFFICIENCY IN BOSNIA AND HERZEGOVINA

by

Alija LEKIĆ and Šemsudin HADŽIEFENDIĆ

Original scientific paper
UDC: 620.9:697.31/.34
BIBLID: 0354-9836, *11* (2007), 3, 85-100

The main sources for power generation in Bosnia and Herzegovina are domestic coals, mainly lignite and brown coals, which are relatively characterized with a high content of sulphur (3-5%) and incombustibles (~30%). From the 70's, use of this type of fuels was not allowed in the city of Sarajevo due to very unfavourable emissions to the atmosphere, during the heating period, and since then Sarajevo has been supplied with natural gas. All the heating installations in the city were reconstructed and adapted.
The district heating system Toplane Sarajevo is supplied with electrical energy from the Public electrical distribution network (Elektrodistribucija Sarajevo) at low voltage (0.4 kV). The boiler-house Dobrinja III-2 (KDIII-2), from the district heating system of Sarajevo Suburb Dobrinja, which was not in use after the war 1992-1995, had a lot of advantages for the reconstruction into the co-generation plant. The Government of Canton Sarajevo financially supported this proposal.
An analysis of co-generations for the district heating system and a selection of most appropriate co-generation systems were made. In the proposed conceptual design, the co-generation KDIII-2 was located in the existing boiler-house KDIII-2, connected with the heating system in Dobrinja.
The operating costs of production of electricity and heat were evaluated in the study and compared with the costs of conventional energy supply to the district heating system. This analysis resulted in economic indicators, which showed that this investment was economically viable, and it also determined the payback period of the investment.
In this paper results of the mentioned study and an overview of co-generation in Bosnia and Herzegovina are presented.

Key word: *co-generation*

Introduction

There are some opinions that the energy sector in Bosnia and Herzegovina (B&H), especially the electric power part of it, is a prosperous one. This optimism is based on the large coal reserves, high hydro-power potential and existing power plants, on one side, and the opportunity to export electricity, and partly coal in some of the neighbouring countries, on the other side.

The total balanced coal reserves in B&H are estimated at 3856 million metric tones (without the reserves of coal mines in Ugljevik, Gacko, and Duvno); of that value,

DOI:10.2298/TSCI0703085L

the reserves of brown coal (calorific values between 11,728 and 18,471 kJ/kg) represent 1330 million tons and that of lignite (calorific values between 8,002 and 11,439 kJ/kg) 2526 million tons. The total hydro-power potential is estimated at 22,050 GWh annually, *i. e.* at 6,126 MW of installed capacity. Preliminary research surveys of oil and gas, which were interrupted by the war, had indicated the presence of promising deposits on a number of sites in certain areas of B&H [1].

Potential for exploitation of geothermal energy, wind energy, solar energy and biomass energy has not been sufficiently explored, but the share of these energy sources in the overall consumption will certainly remain modest for some time. However, the increased use of renewable sources of energy in the world is significant and their potential and feasibility of their use should be analyzed.

In spite of the potential, B&H is importing energy, and about 32% of consumed primary energy was imported in the year 2002, although the consumption of primary energy per capita is lower than the average in the world [2]. (The primary energy consumption per capita in B&H was 44 GJ compared to the average consumption in the world of 69 GJ per capita in 2002). Mainly liquid fuel and natural gas are imported.

The town of Sarajevo initiated the import of natural gas in order to solve the problem with air pollution. Natural gas, at the beginning, was used in boiler-houses for district heating and later on in industry as well, and the gas pipeline system was expanded.

The installed capacity in the thermal power plants in B&H is 1780 MW, and the capacity of hydro-power plants is 1947 MW. (The available capacity of small hydro-power plants of 18.9 MW is not included). Total electric power production in B&H in the year 2003 was 11,240 GWh. (Fifty nine percent of production comes from thermal, and 41% from hydro-power plants). The gross consumption (distributive, direct and losses) in the same year was 10,280 GWh. In the same year, the net export of electricity was 960 GWh [3].

Some of the thermal power plants supply heat for district heating systems and steam for industry, but the amount of energy supplied is not high. Before the war, a certain number of power generation units (14 in total) with the total capacity of 293.6 MW_e were in use in industrial facilities, supplying electricity, process steam and heat, but only four of these units with the total output of 34 MW_e are now available.

Beside the relatively low primary energy consumption per capita, the efficiency of energy use in B&H is very low. The energy intensity indicator for B&H was, in the year 2002, 0.63 toe/1000 US$ compared to the average of 0.29 toe/1000 US$ in the world [2]. This data clearly shows that there should be a significant opportunity for increasing energy efficiency. Since a large part of the energy is used in the residential sector and industry, the use of co-generation might help in accomplishing it.

Some attempts for the combined production of heat and electricity, mentioned above, can hardly be considered as co-generation, especially if it is compared with some countries in Europe where 50% or even more electricity is produced in combined heat and power (CHP) facilities.

Co-generation KDIII-2 – Sarajevo

The district heating system (DHS) Toplane Sarajevo (Power Plants Sarajevo) is the largest company in the power generation and distribution sector in B&H. In Canton Sarajevo DHS has 129 boiler-houses and 184 heating substations. DHS has the heating power 499 MW and 80 km of hot water pipelines, and provides heating for over 46,668 apartments and 250,000 m^2 of office space [4].

Electrical energy costs represent a significant expenditure for DHS and for other public service companies, as well. The electrical energy costs for these companies are dependent not only on the amount of energy consumption, but also on the way, method and time of consumption (rates are dependent on the season and/or time of day). These are the reasons why other public service companies in Canton Sarajevo, besides, DHS were also interested in lowering the electrical energy costs.

For the first co-generation project DHS selected the heating system of Dobrinja – a suburb of Sarajevo. The Bosnia-S Oil Services Co. – Sarajevo carried out a feasibility study [5].

Objectives of the feasibility study were:
- analyze the current situation and the heat and electrical energy supply costs. Perform an analysis of the electrical energy supply for other public service companies as well,
- select an appropriate system, develop a conceptual solution and generate a list of main components of the co-generation system,
- perform an investment cost analysis, including the costs of reconstruction of the existing KDIII-2 boiler-house and the accompanying infrastructure, and
- in the economic part of the study it is necessary to determine the costs of heat and electrical energy produced in the future co-generation plant, and present them in relation to the cost of natural gas and determine the key economic and financial indicators.

Figure 1 depicts average monthly heating loads for the Sarajevo suburb Dobrinja III. The data was obtained based on the measurements of the average heating loads of the KDIII-1 boiler-house, which currently provides heat for Dobrinja III, in the 2003/2004 heating season.

The necessary heating power for the generation of heating energy depends on the outside temperature, so for the lowest outside temperature of 19 °C, the necessary heating power is 17 MW.

The prices of heating energy, or heating costs in Canton Sarajevo, are calculated in KM*/m^2 of heated area (different rates for apartments and office space). In the economic part of the study, the price of heating energy, for comparison purposes, is reduced to the budgetary price of 0.085 KM/kWh.

Analysis of the electrical energy supply includes the entire district heating system of DHS and public service companies: Public transport in Sarajevo (GRAS) and Public lighting (PL). The analysis was performed separately for each company for the summer and winter of 2003 and 2004. For selection and sizing of the future co-generation system it was necessary to include daily electrical loads beside the annual electrical loads.

* KM – currency in B&H; 2 KM = 1 €

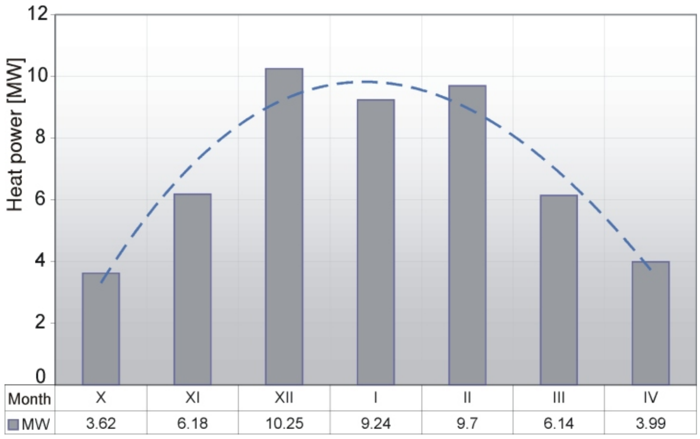


Figure 1. Average heating power (MW), per month, for the 2003/2004 heating season, based on boiler-house operation of 16 hours per day

The goal of the mentioned study was to determine not only the consumption of electrical energy, but also the costs. For selection of the system and development of the proposed solution for a co-generation system for KDIII-2 it was necessary to balance the ratio between the heating and electrical power. Table 1 show the annual consumption of electrical energy for 3 public service companies (PSC): DHS, GRAS, and PL (maximal power, costs, average prices, supply).

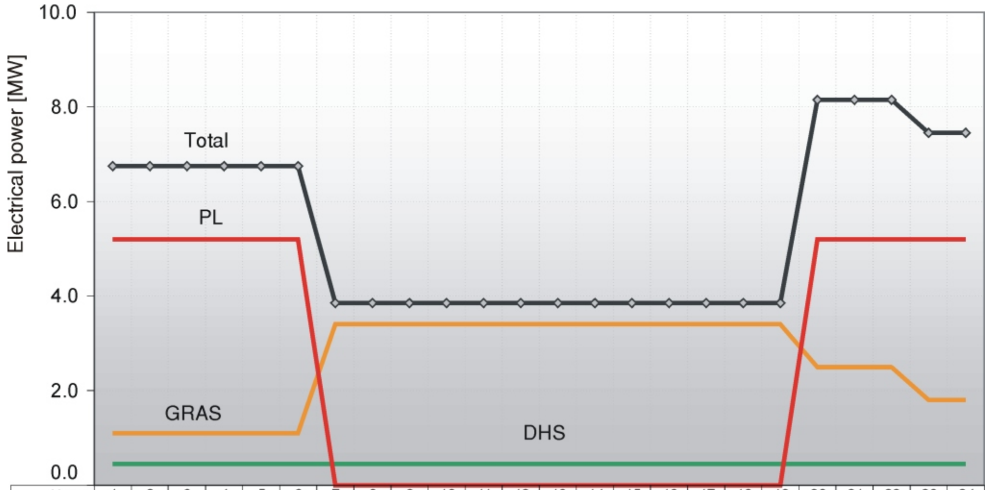
Table 1. Ranges of maximal power, used energy, costs and prices for electrical energy in 2003

PSC	Max power	Active energy		Electrical energy costs		Average prices of electrical energy	Electrical energy supply
	[MW] (monthly)*	[GWh]	[%]	[KM] (000)	[%]	[KM/kWh]	
DHS	0.3-3.8	12.00	23	2,263	29	0.19	LV
GRAS	3.1-5.7	18.25	35	2,241	29	0.123	10 kV
PL	5.2-6.2	21.88	42	3,332	42	0.152	LV
Total	8.7-15.7	52.13	100	7,836	100	0.15	

* Available data for 2002

Ranges of minimum daily loads for the summer period (minimal consumption) are: 3.4-6.5 – 7.3-8 MW, which are shown on fig. 2, while fig. 3 shows the ranges of daily loads during the heating season – winter period.

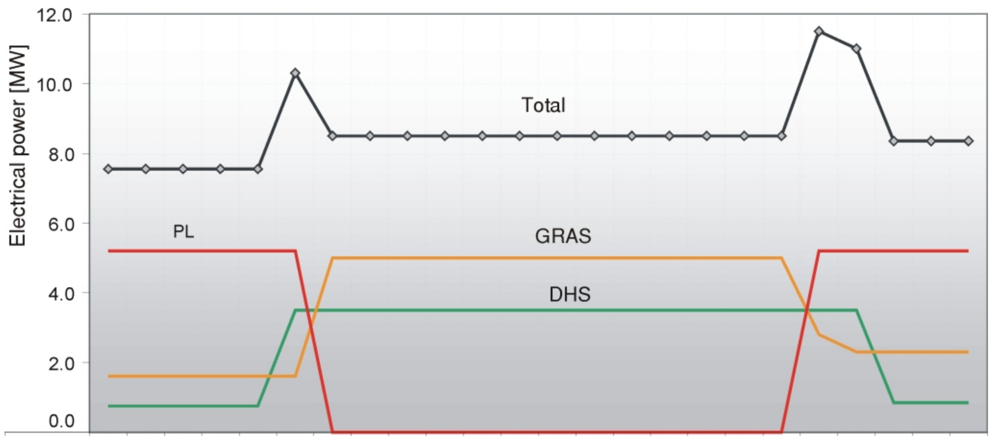
The future co-generation will be a part of the energy system of Canton Sarajevo, connected to the public electrical distribution network and to the existing district heating system. The connection to the public electrical distribution network means that the co-generation plant KDIII-2 will deliver the generated electricity to the network (10 kV),



Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
DHS	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
GRAS	1.1	1.1	1.1	1.1	1.1	1.1	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	2.5	2.5	2.5	1.8	1.8
PL	5.2	5.2	5.2	5.2	5.2	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	5.2	5.2	5.2	5.2
Total	6.8	6.8	6.8	6.8	6.8	6.8	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	8.2	8.2	8.2	7.5	7.5

Figure 2. Daily loads (MW), May-September (Summer) – expected minimum values

which will continue to supply end users. At the same time, the missing electrical energy will be purchased from the network. The generated heating energy will be delivered to



Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
DHS	0.8	0.8	0.8	0.8	0.8	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	0.9	0.9	0.9
GRAS	1.6	1.6	1.6	1.6	1.6	1.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	2.8	2.3	2.3	2.3	2.3
PL	5.2	5.2	5.2	5.2	5.2	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	5.2	5.2	5.2	5.2
Total	7.6	7.6	7.6	7.6	7.6	10.3	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	11.5	11.0	8.4	8.4	8.4

Figure 3. Daily loads (MW) for the period of October to April (Winter) 2003-2004

the district heating system for the suburb Dobrinja III and connected with the existing (rebuilt) boiler-house KDIII-1, providing the possibility of parallel operation with the cogeneration plant KDIII-2.

After the completion of comprehensive analyses the following conclusion was made: a co-generation system with a gas turbine, as its key component, is the best solution.

For the generation of heating and electrical energy for all three public service companies (shown in previous graphs) which have very different profiles of summer-winter energy needs and especially very different daily loads of electrical energy, it is difficult to find an optimal co-generation solution, which will cover total energy needs of all three companies.

Table 1 shows maximal electrical powers for the 3 companies, which will have to be supplied by the future co-generation. It should pointed out that this data represents maximal annual loads and they are not relevant for the sizing of the turbo-generator set (TGS) of the co-generation plant, but rather the data from the daily load diagram. In the critical winter period these powers are ca 8.0-9.0 MW_e. A TGS of this power, working continuously, would have the heating power of around 12.5 MW_t, which significantly exceeds the needs of 10.25 MW_t. Also, a 8.0-9.0 MW_e TGS would not physically fit into the available space in the boiler-house KDIII-2, and it significantly exceeds the planned investment costs.

It was concluded that the optimal solution is to develop future co-generation capacities in two stages – by building two 4.0-5.0 MW_e co-generation plants. Co-generation of this power would satisfy high priority needs of Toplane and ca. 80% of PL needs and that in the critical winter period. The public electrical distribution network would continue to supply GRAS with electrical energy.

Average heating energy needs are around 7.58 MW_t, which can be entirely satisfied by a TGS of 4.0-5.0 MW (having the lowest heat to power ratio of 1.2) and supplementary firing. Only when the outside temperature drops below –3 °C would the existing boiler-house KDIII-1 be put into joined operation.

In the proposed conceptual solution of KDIII-2 co-generation plant shown on fig. 4, graphs of daily loads supplied in the critical winter period are given. Based on all of the above, the selected co-generation system KDIII-2 has to fulfil the following requirements:

(1) co-generation plant KDIII-2 should be designed with one turbo-generator set of 4.0-4.5 MW_e and one waste heat recovery boiler (WHRB) with supplementary firing,
(2) co-generation KDIII-2 is of the classic topping system type, which is characterized by primary production of electrical energy and a low heat power ratio (HPR),
(3) TGS and WHRB should be located in the KDIII-2 boiler-house. It should be checked if there is enough available space in the boiler-house based on the actual equipment drawings, which are to be provided by the equipment supplier, and
(4) generation of electricity and heating energy in the KDIII-2 co-generation plant.

Winter operation

Electrical energy: Complete coverage of the needs of Toplane (of highest priority) and partial coverage of the needs of PL. Heating energy: Production of heating en-

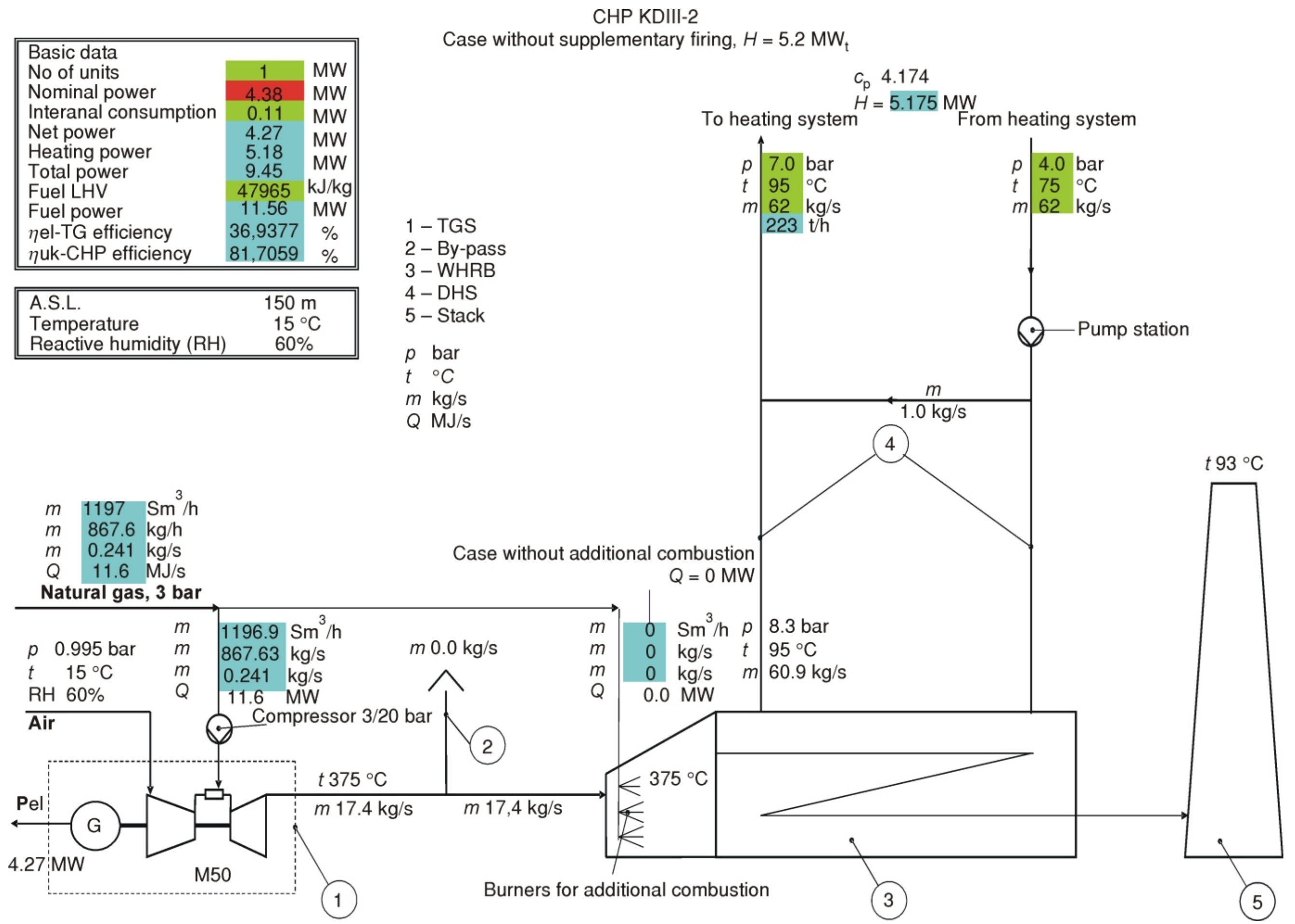


Figure 4. Heat generation schematic of the KDIII-2 co-generation plant with energy and material balance without additional combustion

ergy for the consumers of Dobrinja III from the available energy of waste gases. During the coldest winter period supplemental firing of the WHRB and the KDIII-1 boiler-house will be necessary.

Summer operation

There are two possible options: Putting the co-generation plant out of operation from May to September or production of electrical energy for GRAS, PL, and DHS (minimum needs). Both options will be considered. Decision about the summer operation of the co-generation plant KDIII-2 will depend on the production costs of electrical energy in co-generation, *i. e*. on the price of natural gas for large consumers.

Turbo-generator set

The selected gas turbine is designed for continuous base operation in a co-generation plant and includes a gas turbine with a compressor connected to a common shaft with the electrical energy generator, which is equipped with a computer based regulation, control and protection system and other equipment. TGS is designed for indoor installation, it is delivered on a single base, factory tested and examined. The TGS delivery scope includes a WHRB, which is mounted to the CHP plant on site.

Basic data of the selected turbine

Net electrical power (at generator)	P_{net}	4.27 MW_e
Heating power of waste gases	H	5.18 MW_t
Totalpower	$(P_{net}+ H)$	9.45 MW
Turbine efficiency rate	η_T	36.94%
Total efficiency rate of CHP	η_{CHP}	81.71%

Turbine Mercury 50 is suitable for co-generation of the topping system type and has a H/P ratio equal to 1.22 (based on H/P = 5.18/4.27), which is also required in our

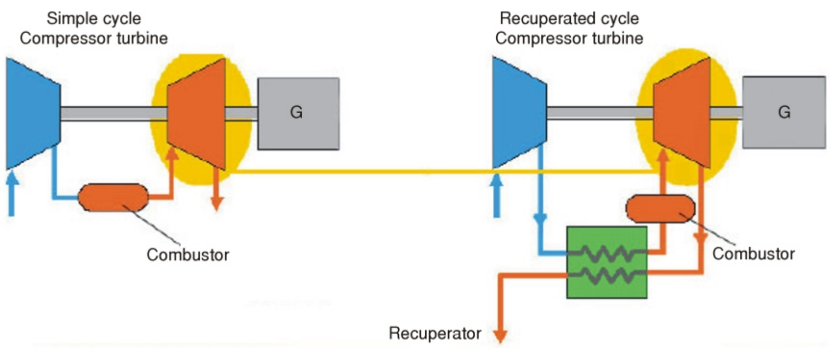


Figure 5. Cycle with recuperation

case. Gas turbine Mercury 50 is designed with a heat recuperator (fig. 5). Heating of air to the required temperature level before it enters the turbine is accomplished in the heat recuperator of waste gases, and in this way the efficiency rate of the turbine is considerably increased.

Environmental protection

The co-generation plant KDIII-2 will not produce solid or liquid waste. The amount of CO_2 per 1 MWh_e is around 3 times lower than in conventional thermal power plants. The turbine Mercury 50 is equipped with a patented device for lean premixed combustion which is built into the combustion chamber and therefore the guaranteed emission levels of pollutants are shown in tab. 2.

Table 2. Guaranteed emission levels of pollutants

Pollutant	[ppm]	[mg/Nm^3]
NO_x	5	11
CO	10	13
UHC	10	8

According to new law on air in the Federation of Bosnia and Herzegovina, which is compliant with the EU Directives, the highest emission levels of NO_x for combustion chambers below 50 MW_t (0.35-10 MW_t) are 100-125 mg/Nm^3. The TGS, as the main source of noise is planned for indoor installation and it is wrapped with external protection in order to attain a sound insulation level of around 85 dB (A) at ~1 m distance from the TGS, which is also within the limits set by EU Directives.

Therefore, it could be concluded that the complete co-generation plant satisfies set standards for environmental protection.

Waste heat recovery boiler

During continuous co-generation with nominal power of the TGS of 4.27 MW_e, waste gases from the turbine have temperature of ~375 °C. At these operating conditions the boiler has the heating power of 5.18 MW_t, which is used for production of heat energy. Power increase is achieved by adding a supplementary combustion device which will increase the temperature of waste gases to ~620 °C and raise the heating power to 10.1 MW_t in continuous operation, which is sufficient for heating power during the cold winter period. That is the maximal heating power of the KDIII-2 co-generation plant. If the needs for heating energy exceed these values, a parallel operation of the boiler-house KDIII-1 is required.

Energy and material balance – Co-generation KDIII-2

The heating energy scheme of co-generation KDIII-2 with material and energy balance is calculated for two characteristic operations of co-generation: Continuous operation of co-generation KDIII-2 during the winter period, with nominal net power P_e = 4.27 MW_e and with heating power H = 5.18 MW_t, without supplementary firing, and with heating power H = 10.1 MW_t with supplementary firing.

For both operation types TGS continuously produces electrical energy (power of 4.27 MW_e) and delivers it to the electrical distribution network and also produces heating energy (power of 5.18 MW_t) on the basis of complete exploitation of the heat energy of waste gases, but with additional combustion it attains the heating power of H = 10.1 MW_t.

Overview of operational characteristics of the KDIII-2 co-generation plant

The KDIII-2 co-generation plant with the selected TGS, with the power of 4.27 MW_e, in continuous operation for ca. 5088 hours (winter period), will produce electrical energy in the amount of 21.725 GWh_e, *i. e.* 35.458 GWh_e, and for ca 8034 working hours (winter + summer period) and it will cover the total needs of DHS and around 80-85% of the PL needs. Depending on the needs, co-generation would produce heating energy in the range from 26.355 to 51.389 GWh_t[(1)]. During the summer period, it is possible to continue to operate and to produce electric energy for the needs of GRAS, PL and DHS (minimum needs).

Heat that is produced in co-generation KDIII-2 will partly cover the needs of the consumers of Dobrinja III with the heating power of 5.18 MW_t. In addition, depending on the outside temperature, through automatic control, the additional combustion will be switched on and the production of heat will be increased. Through additional combustion with the fuel consumption of 528 Sm^3/h, the heating power of co-generation will be increased to 10.1 MW_t. This heating power will be sufficient to heat all consumers of Dobrinja III, provided that the outside temperature is above –3 °C[(2)], and when the temperature drops below –3 °C[(2)], the KDIII-1 boiler-house will put into parallel operation.

Gas consumption during the heating season would be around 6.214,187 Sm^3 without additional combustion, *i. e.* 8.776,800 Sm^3 with additional combustion and maximal heat capacity of 10.1 MW_t.

Operational characteristics of the KDIII-2 co-generation plant

The opertional characteristics are shown on fig. 6.

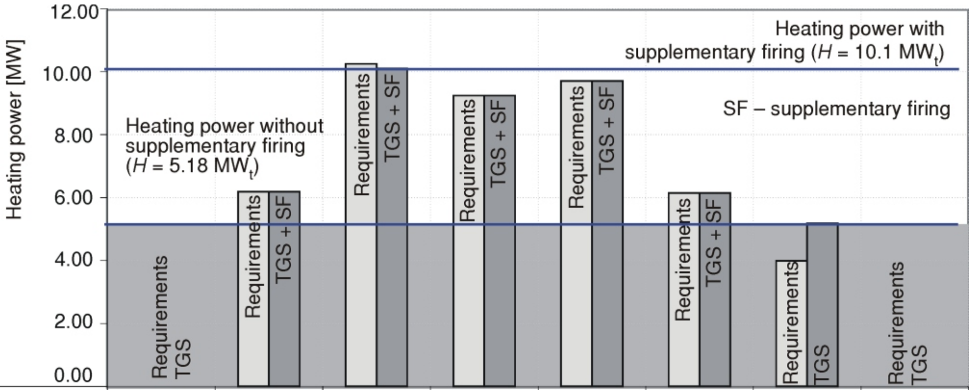
Coverage of daily electrical energy needs are given for winter period (fig. 7) and summer period (fig. 8).

Economic part

The goal of the economic analysis of KDIII-2 co-generation is to make a realistic estimate of the investment feasibility based on a set of dynamic indicators related to:

– determination of the production costs of co-generation products (heat and electrical energy) and their profitability threshold, *i. e.* their price sensitivity,

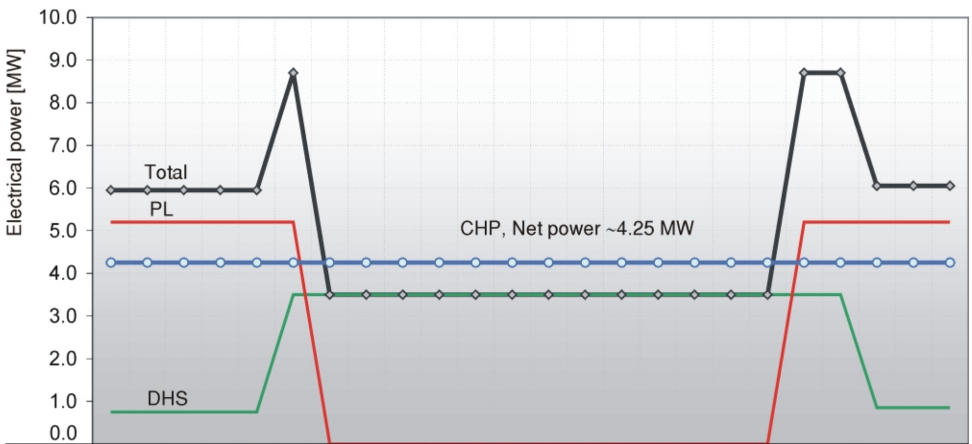
[1] The range of produced heat is given for the range of available heating power (5.18-10.1 MW_t)
[2] Data provided by DHS



Month	X	XI	XII	I	II	III	IV	V
Requirements	0.00	6.18	10.25	9.24	9.70	6.14	3.99	0.00
TGS	0.00	6.18	10.10	9.24	9.70	6.14	5.18	0.00

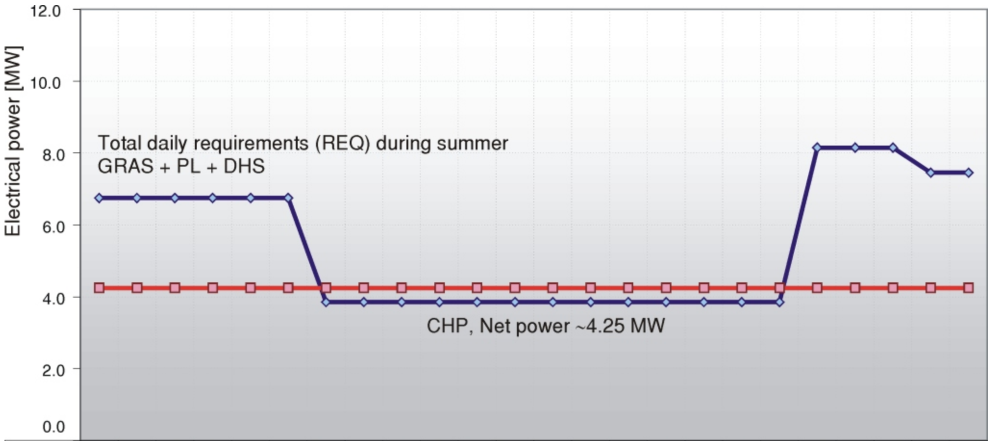
Figure 6. Coverage of heating power needs by the KDIII-2 co-generation plant without supplementary firing (5.18 MW$_t$) and with supplementary firing (10.10 MW$_t$)

– determination of the net present value (NPV),
– determination of the internal rate of return (IRR), and
– determination of the payback period.



Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Total	6.0	6.0	6.0	6.0	6.0	8.7	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	8.7	8.7	6.1	6.1	6.1
DHS	0.8	0.8	0.8	0.8	0.8	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	0.9	0.9	0.9
PL	5.2	5.2	5.2	5.2	5.2	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	5.2	5.2	5.2	5.2
CHP	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3

Figure 7. Coverage of daily electrical energy needs (total needs of DHS and 80% of PL) by KDIII-2 co-generation production of power of 4.27 MW$_e$ for the winter period



Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
REQ	6.8	6.8	6.8	6.8	6.8	6.8	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	8.2	8.2	8.2	7.5	7.5
CHP	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3

Figure 8. Coverage of daily electrical energy needs for the summer period (GRAS, PL, and DHS) by KDIII-2 co-generation production

It is necessary to point the following specific problems related to the first co-generation plant of this type in B&H:

(a) The price of natural gas in B&H of 0.42 KM/Sm^3 is the same for small consumers (households) and for large energy and industrial consumers (DHS). This was used in the basic version of the feasibility study of KDIII-2 co-generation. However, an additional study named Alternative natural gas supply for Toplane was also made. Based on this proposal DHS would be supplied with natural gas directly from the main gas pipeline and the price of gas (for the largest consumer of natural gas in B&H) would be 0.33-0.35 KM/Sm^3. For this reason the economic indicators of feasibility of KDIII-2 co-generation are presented in relation to the price of natural gas.

(b) The new law on electrical energy in B&H has been passed in the middle of 2002. To this date there was not a single private, independent producer of electrical energy that delivers, *i. e.* sells, electricity to the Public electrical distribution network. The first producer and supplier of electrical energy in B&H should be the KDIII-2 co-generation plant, *i. e.* Toplane. Under what conditions, *i. e.* selling price, is to be determined by the State regulatory agency for electrical energy. That is the reason why the IRR and the payback period are shown on a chart in relation to the price of electrical energy.

Results of the economic analysis of the KDIII-2 co-generation plant

Based on the data previously presented in the proposed (technical) conceptual solution, an economic profitability analysis of co-generation was made, and the results of this analysis are given in tab. 3.

Table 3. Sales assortment, total revenue and (direct) material expenses – projection at an annual level

			Heat	Electricity	Total
1	Production/service scope	MWh	15,069.60	21,725.76	
2	Average sales price	KM/MWh	84.86	164.77	
3	Revenue	KM	1.278,806.26	3.579,728.88	4.858,535.14
4	Costs of base fuel – gas (total)	KM	686,962.47	1.922,996.07	2.609,958.54
5	Key coefficient for distribution of expenses (1.00)		0.26	0.74	1.00

Data in tab. 3 are calculated based on monthly revenues and direct material expenses which were studied in detail in the economic analysis. The key coefficient for distribution of expenses was formed based on the product's contribution to the annual revenue.

An internal analysis determined the profitability threshold and price sensitivity of this project. The analysis showed that the profitability threshold is 43% for both co-generation products (heat and electrical energy), which leaves enough space for lower sales levels of these products.

Profitability assessment of the KDIII-2 co-generation plant

The market profitability assessment of the project is presented by a dynamic indicator set, and the results are shown in tab. 4.

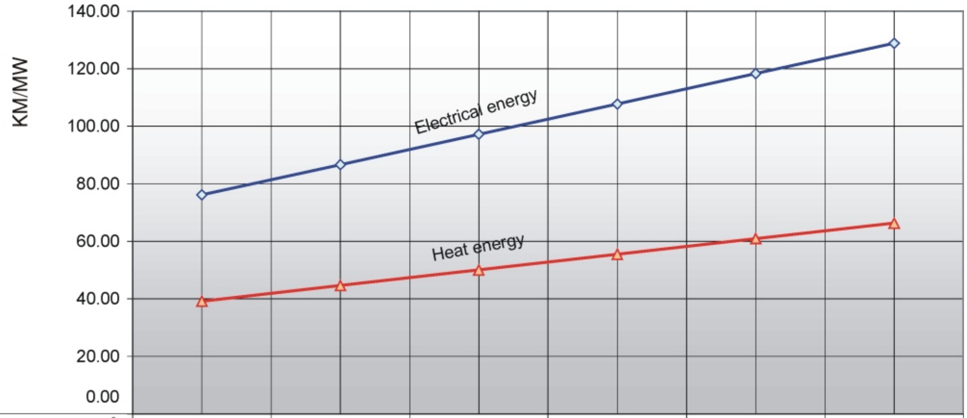
Table 4. Dynamic indicators

Internal rate of return (IRR) [%]	14.83
Net present value (NPV)	11.767,151.73
Payback period [years]	4.99

These dynamic indicators confirm that the investment is profitable and viable. The costs of production of electrical and heat energy are directly related to the price of gas, and the price of gas has the biggest influence on the production costs. As pointed out earlier, the present situation regarding the supply of natural gas is very unfavourable from the aspect of costs, especially when one considers that outside of B&H co-generation plants and companies like DHS enjoy a special status regarding the price of their primary fuel. The following chart (fig. 9) shows the costs of production of heat and electrical energy in relation to the price of natural gas for the selected basic case.

The technical part of the study analyzed the possibility and operating conditions of the co-generation plant in the summer period, whether it would operate as a classical power plant or produce both, electrical energy and domestic hot water (suburb Dobrinja III). The following conclusions were made.

If the heat energy of exhaust gases would not be utilized, *i. e.* when this unexploited heat energy would be directly released into the environment, the profitability



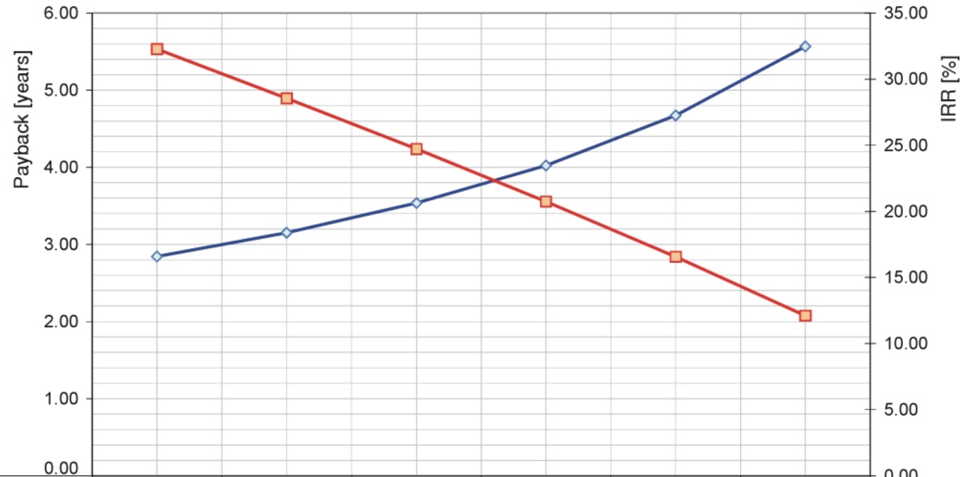
KM/Sm^3	0.20	0.25	0.30	0.35	0.40	0.45
CKII – MWh_e	76.13	86.67	97.21	107.74	118.28	128.82
CKII – MWh_t	39.21	44.64	50.06	55.49	60.92	66.34

Figure 9. Production costs of electrical and heat energy in relation to the price of natural gas

threshold related to the price of gas would be 0.375 KM/Sm^3. In accordance with these considerations it was concluded that if natural gas would be supplied from the main gas pipeline (BH Gas) at the price 0.35 KM/Sm^3, *i. e.* 0.33 KM/Sm^3, the payback period would be 4.18 and 3.84 years, respectively, with the IRR of 19.66 and 22.11%, respectively (fig. 10). An additional benefit would come from that fact the co-generation plant would operate the whole year, which is very favourable from the aspect of utilization of the rented natural gas transport capacities (the main gas pipeline rented out the whole year, whether used or not).

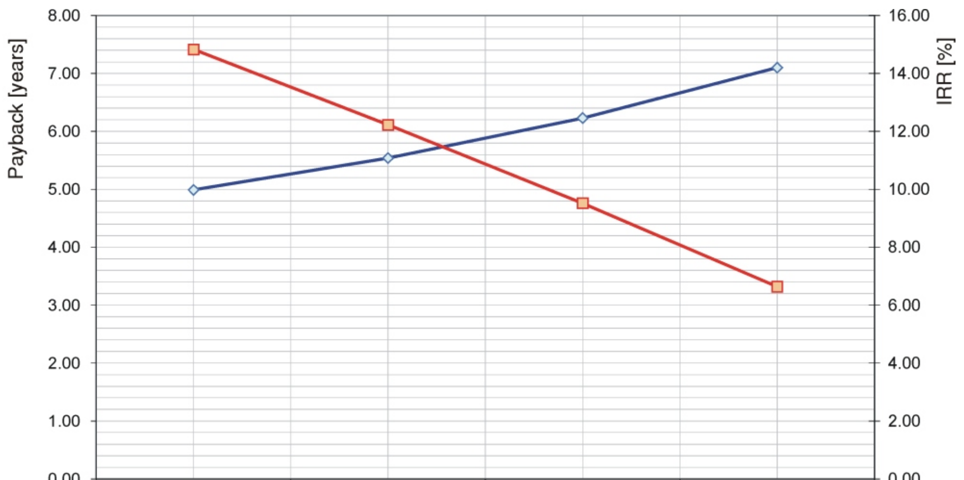
The production and distribution of domestic hot water would require an additional investment of ca 2.800,000.00 KM, and the economic analysis showed that the payback period would be ca 15 years. Besides that, the apartment owners were not interested in this subsequent installation of a hot water supply system in their apartments.

As previously stated, the KDIII-2 co-generation plant would deliver all of the produced electrical energy to the medium voltage (10 kV) network of the Public electrical distribution network (Elektrodistribucija Sarajevo), and consumers (DHS and PL) would continue to receive energy from this network. The ratio of delivered to received electrical energy would be 1:1. The matter of payment of services of Elektrodistribucija Sarajevo is still to be resolved at the state level. Figure 11 shows the relation between the economic indicators (IRR and payback period) and the distribution costs. The distribution costs are shown as a percentage of the primary, production cost of electrical energy in co-generation.



KM/Sm³	0.20	0.25	0.30	0.35	0.40	0.45
Payback	2.84	3.15	3.53	4.02	4.67	5.57
IRR	32.28	28.55	24.72	20.74	16.57	12.12

Figure 10. IRR and payback period in relation to the price of natural gas



	0%	5%	10%	15%
Payback	4.99	5.54	6.23	7.1
IRR	14.83	12.23	9.52	6.64

Cost distribution of electrical energy (of basic electrical energy price)

Figure 11. IRR and payback period in relation to the costs of electrical energy distribution

Conclusions

(1) Based on the indicators presented in the Feasibility study co-generation KDIII-2 represents a profitable investment even in the worst case scenario where the price of the base fuel – natural gas – is 0.42 KM/Sm^3.

(2) A process with the objective of determining a stimulative price of natural gas for large and industrial consumers in B&H has been started. It is expected that this price of natural gas will be around 0.35 KM/Sm^3. In this case, the KDIII-2 co-generation would have the following indicators:
   - internal rate of return of 19.66%, and
   - payback period of approximately 4.18 years.

(3) It is expected that the services of Elektrodistribucija Sarajevo, which are to be determined by the State regulatory agency for electrical energy in B&H, will cost approximately 5% of the production cost of electrical energy in co-generation (in accordance with conditions in EU countries).

(4) Construction of the first co-generation plant in B&H should start in the second half of 2005.

References

[1] ***, Map of DEG Potential in WB, UZ-FSB, 2005
[2] ***, Key World Energy Statistics, IAE, 2004
[3] ***, The Accomplishment of Electric Energy Balance for the Period January-December 2003 (in Bosnian), ZEKC, Sarajevo, 2004
[4] ***, Power plants – Yesterday, Today, Tomorrow (in Bosnian), Toplane, Sarajevo, 2004
[5] Hadžiefendić, Š., Ibišević, A., Jovanović, N., Hajro, I., Šehović, H., Salihbegović, A., Bilalagić, I., Hodžić, A., Co-Generation KDIII-2, Feasibility study, Bosna-S Oil Services Co., Sarajevo, 2005

Author's addresses:

A. Lekić
University of Sarajevo, Mechanical Engineering Faculty
9, Vilsonovo šetalište, Sarajevo, Bosnia and Herzegovina
E-mail: lekic@mef.unsa.ba

Š. Hadžiefendić
Bosna-S Oil Services Company Sarajevo
26, Nova, Sarajevo, Bosnia and Herzegovina
E-mail: semso.hadziefendic@bosna-s.ba

Paper submitted: July 31, 2006
Paper revised: April 15, 2007
Paper accepted: April 28, 2007