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ENVIROMANTAL AND FINANCIAL ASPECTS OF REPLACING COAL AND FUEL OIL WITH NATURAL GAS ON THE "HOME LOCATION" OF "ENERGY" LTD.

Abstract: *This paper briefly presents a heat-distribution system of the city of Kragujevac, and the structure of "Home location" of city power plant "Energy" Ltd. Emphasis is placed on the consumption of energy on the "Home location" and on distribution of fossil fuels involved in consumption. Since coal as fuel dominates, with its share around 77% in the energy consumption of plant "Home location" of the total energy consumed by this plant, carbon emissions generated by burning coal and fuel oil in boilers are calculated, as well as savings that would be achieved by replacing these fuels with natural gas are reviewed. If the main criterion for a fuel replacing would have been CO2 emission, replacement of coal and fuel oil with natural gas would have achieved reducing of carbon dioxide emission by 43%, where the labor costs of boiler plants would have almost doubled. At this point, we emphasize that, in the course of the said balance sheet, are noticed a very considerable efforts "Energy" Ltd. on purification of flue gases emitted by their plants, and these efforts are very highly rated.*
Keywords: *coal, natural gas, fuel oil, carbon dioxide emissions*

1. INTRODUCTION

The city of Kragujevac has a centralized communal heat distribution system. The heating energy is distributed to the consumers from multiple central sources, the biggest of which is "Home location".

Of 315 MW installed power at the "Home location" for the production of heating energy 80% of installed capacity runs on coal and fuel oil and 20% on gas. It is important to point out that besides already mentioned "Home location" there are 9 more regional (non-matrix) energy plants situated at different parts of city and 2 steam turbines used for production of electric energy located at the "Home location". All these energy plants together with the primary pipeline network make the company "Energetika" Ltd and represent heat distribution system of Kragujevac city. There are 5 boiler units at the "Home location". The two smaller boilers use gas as fuel, whereas the rest use coal and fuel oil. In the chart below (Table 1) basic data about installed capacities for the production of heat energy on the "Home location" are given [1].

Table 1. Basic data about installed capacities of heat energy

Label of furnace unit	Fuel	Type of furnace unit	Year of manufacture	Capacity [MW]	Total capacity [MW]
K1	Gas	steam	1961	31,5	304
K2	Gas		1962	31,5	
K3	coal/fuel oil		1970	63	
K4	coal/fuel oil		1971	63	
K5	coal/fuel oil		1980	115	

Boilers mostly work in on/off order, depending on heat load (weather conditions, consumer needs, etc.), and they often don't work at full capacity. During the heating seasons of 2010/11 and 2011/12 the primary choice (to satisfy the basic heating requirements) was to use coal boilers and then the natural gas boilers.

2. CONSUMPTION OF ENERGETIC SOURCES AT THE „HOME LOCATION" OF ENERGY PLANT „ENERGETIKA" LTD KRAGUJEVAC

Energy plant "Energetika" Ltd ("Home location") cannot work properly without consumption of specific energetic sources, and without providing the "Home location" with coal, fuel oil, natural gas and electricity. For clearer overview, the analysis of consumption of energetic sources, based on data of firm's consultant team was made and given in the Table 2 [2]. It is important to mention that the data about gas consumption were obtained in standard cubic meters of gas[i]- (Sm^3), and are given in the standard cubic meters of gas[ii]- (Nm^3), under condition that from "combined law of gas[iii]" follows:

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2} \quad \Rightarrow \quad V_2 = \frac{T_2}{T_1} \times V_1,$$

$$p_1 = p_2 = const.$$

This makes:

$V_2\left(Nm^3\right) = 0{,}9479 \times V_1\left(Sm^3\right)$, where the value of 0.9479 is the conversion factor (temperature ratio). The so called "industrial" temperature of 15 °C was taken into account. The conversion from Sm^3 into Nm^3 is necessary to calculate equivalent energy.

Factors used for recalculation are:

- truck coal: 1t = 3480 [kWh] = 12.5 [GJ],
- fuel oil: 1t = 11390 [kWh] = 41,004 [GJ],
- natural gas: $1Nm^3$ = 9.26 [kWh] = 0,0333 [GJ].

Table 2 Overview of consumption of energetic sources (equivalent energy) - 2011/2012

Energy sources		Coal	Fuel oil	Natural gas	Electricity	TOTAL
Consumption		99.000	2.850	7.453.002	99.000.000	
Unit of measure		ton (t)	ton (t)	Nm^3	kWh	
Equivalent energy	**GJ**	1.237.500	116.900	248.000	356.400	**1.956.800**
	%	63	6	13	18	**100%**

After analyzing the data (Table 2) and the following graphs (Figure 1) it is apparent that coal is the most dominant energetic source in the consumption at the "Home location". If only the consumption of fuel is taken into consideration (and if the electricity is left out) it can be concluded that 77% of equivalent fuel energy is coal, 16% is natural gas and 7% is fuel oil (Figure 2).

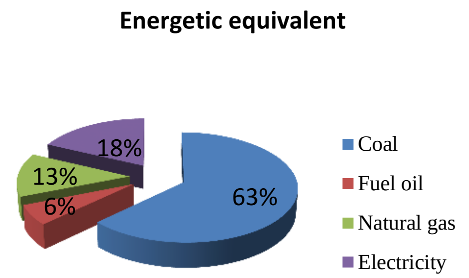

Figure 1 Consumption of fuel and electricity – energetic equivalent for the "Home location"

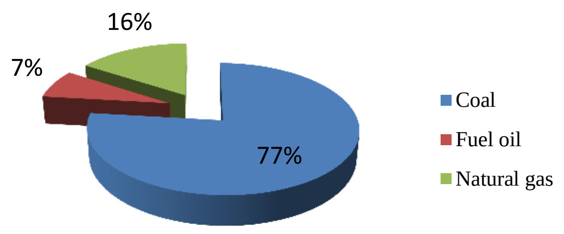

Figure 2. Consumption of fossil fuel – energetic equivalent for the "Home location"

3. CHARACTERISTICS, EXPENSES AND ENERGETIC SOURCES EMISSION

Total consumption for the heating season of 2011/12 was about 99.000 tons of truck coal and 2.850 tons of fuel oil. The term truck coal is used for coal that has the quality bordering between lignite and brown coal, etc. which has the heating power of 12.5 GJ/t.

Emission factor for this type of coal is about 100 t/TJ (Table 3) ([3],[4]).

Table 3. Characteristics of truck coal - 2011/2012

CHARACTERISTICS OF TRUCK COAL			
Fuel type	**Size**	**Value**	**Unit**
Truck coal	Consumption	99.000	t
	Emission factor	100	$t(CO_2)/TJ$
	Heating power	12,5	GJ/t
	Expenses	6.009.300	€

Heating power of fuel oil is between 38 and 42 GJ/t, whereas the emission factor for this type of fuel is 76.9 t/TJ (Table 4) ([5],[6]).

Table 4. Characteristics of fuel oil - 2011/2012

CHARACTERISTICS OF FUEL OIL			
Fuel type	**Size**	**Value**	**Unit**
Fuel oil	Consumption	2.850	t
	Emission factor	76,9	t(CO_2)/TJ
	Heating power	38 - 42	GJ/t
	Expenses	997.500	€

The equivalent for this amount of coal and fuel oil, necessary for heating of the city, would be 40.4 million Nm^3 of natural gas, supplied by public company "Srbijagas".

$$\boldsymbol{total_{natural_{gas}}} = \frac{(\boldsymbol{energy_{coal}} + \boldsymbol{energy_{oil\_fuel}})}{\boldsymbol{heat\_content_{natural\_gas}}}$$

This supplier guaranties the minimal heating power of 33.3 MJ/m^3. The emission factor for natural gas of this quality is 56.1 t/TJ, which is almost half the amount than the already mentioned coal (Table 5) ([3],[4]).

Table 5. Characteristics of natural gas - 2011/2012

CHARACTERISTICS OF NATURAL GAS (Srbijagas)			
Fuel type	**Size**	**Value**	**Unit**
Natural gas	Consumption	40.400.000	Nm^3
	Emission factor	56,1	t(CO_2)/TJ
	Heating power	33,3	MJ/m^3
	Expenses	14.400.000	€

The price of gas required for heating, which would replace coal and fuel oil, would be approximately 14.4 million €. This amount, compared to 7 million € for coal and fuel oil, is definitely not profitable.

Analyses of emissions which occur during the combustion of fossil fuels show that "Energetika" Ltd emitted just above 132 thousand tons of carbon dioxide into the atmosphere while burning up coal and fuel oil for the city's heating needs from its matrix location during the heating season of 2011/12.

$$\boldsymbol{CO2_{emission_{coal}}} = total_{coal} \times heat\_content_{coal} \times CO2\_emission\_factor_{coal}$$

$$\boldsymbol{CO2_{emission_{oil_{fuel}}}} = total_{oil\_fuel} \times heat\_content_{oil\_fuel} \times CO2\_emission\_factor_{oil\_fuel}$$

$$\boldsymbol{CO2_{emission_{total}}} = CO2\_emission_{coal} + CO2\_emission_{oil\_fuel}$$

If it were to use gas instead of coal, the emission would be reduced to 75.4 thousand tons of carbon dioxide that is 56.5 thousand tons less, which is a significant reduction of emission of the main cause of the greenhouse effect. (Table 6, Figure 3).

$$\boldsymbol{CO2_{emission_{natural_{gas}}}} = energy_{natural\_gas} \times CO2\_emission\_factor_{natural\_gas}$$

$$\boldsymbol{CO2_{emission_{reduction}}} = CO2\_emission_{total} - CO2\_emission_{natural\_gas}$$

The emission of carbon dioxide is calculated according to the relation:

***Emission of CO2** = fuel consumption × emission factor × oxidation factor*

The consumption of coal is given in energy unit measure [TJ], assuming that the oxidation factor is 1, that is that the ashes have no remaining carbon [3].

Table 6. Energetic sources emission - 2011/2012

CARBON DIOXIDE EMISSION		
Fuel type	**Emission**	**Unit**
Coal and fuel oil	132.000	t(CO_2)
Natural gas	75.460	t(CO_2)
Profit	56.540	t(CO_2)

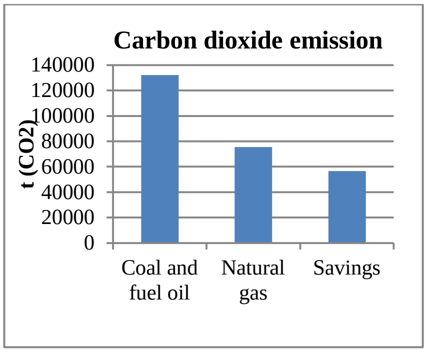

Figure 3. Carbon dioxide emission and eventual savings

4. CONCLUSION

This paper shows the overview of installed boiler units, the characteristics of energetic resources as well as their consumption percentage. Special attention is paid to calculation of carbon dioxide emissions which occur as the side effect of fossil fuel combustion and to the eventual savings in emission and operative costs. Based on the obtained results the conclusion is that by replacing coal and fuel oil with natural gas the emission of main causer of greenhouse effect would be reduced by 43%. In that way, the negative effect on the environment and the atmosphere would be significantly reduced. On the other hand, the operative costs of the „Home location“ facility of the „Energetika“ Ltd company would double, which greatly questions the justification of this action.

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[i] - ***Standard cubic meter of natural gas (Sm^3)*** *is cubic meter that natural gas occupies at the temperature of 15-25 °C (depending on industry temperature) and atmospheric preassure (101325 Pa).*

[ii] - ***Normal cubic meter of natural gas (Nm^3)*** *is cubic meter that natural gas occupies at the temperature of 0 °C and atmospheric preassure (101325 Pa).*

[iii] -***The combined gas law*** *is obtained by combining Charles's law, Gay-Lussac's law and Boyle–Mariotte gas law. This law shows the interdependence of the two gas condition parameters (p, V or T), where the third parameter and amount of gas are constant.*