ISSN 1864-6168
UDK 62

ANALYSIS AND SELECTION OF THE MOST FAVORABLE ENERGY GENERATING PRODUCT FOR THE HEATING REQUIREMENTS OF A PRODUCTION PLANT

ANALIZA I IZBOR NAJPOVOLJNIJEG ENERGENTA ZA TOPLINSKE POTREBE PROIZVODNOG POGONA

Ante Čikić, Antonio Radić

Review article

Abstract: *The analysis and selection of the most favorable energy generating product for the combustion and transformation into thermal energy for technological needs, heating and preparation of consumable hot water (CHW) of a production plant in the continental climate area were carried out. The analyzed energy generating products are: natural gas, biogas, wood chips, pellets and extra light heating oil. Even with 1.5 – 2.0 times higher investments in thermal energy plant, renewable wood chips are, from the ecological and economical perspective, still the most favorable drive fuel for the production of thermal energy. In this case the price of 1kWh of thermal energy is several times lower (3 – 7 times) than the price of 1kWh of thermal energy obtained by the combustion of other analyzed drive fuels. The increase in the unit price of wood chips does not strongly affect the sustainability and cost–efficiency of the price of 1 kWh of thermal energy. The emission of harmful gases into the environment is the lowest.*

Key words: *natural gas, biogas, wood chips, pellets, extra light heating oil, the most convenient energy generating product*

Pregledni rad

Sažetak: *Provedena je analiza i izbor najpovoljnijeg energenta za izgaranje i pretvorbu u toplinsku energiju za tehnološke potrebe, grijanje i pripremu PTV – e proizvodnog pogona u kontinentalnom klimatskom području. Analizirani energenti su: prirodni plin, bioplin, drvna sječka, peleti i ekstra lako loživo ulje. I uz 1,5 – 2,0 puta veća investicijska ulaganja u termoenergetsko postrojenje obnovljiva drvna sječka je ekološki i ekonomski najpovoljnije pogonsko gorivo za proizvodnju toplinske energije. U tom slučaju cijena 1 kWh toplinske energije je višestruko manja (3 – 7 puta) od cijene 1 kWh toplinske energije dobivene izgaranjem ostalih analiziranih pogonskih goriva. Rast jedinične cijene drvne sječke osjetljivo ne utječe na održivost i ekonomičnost cijene 1 kWh toplinske energije. Emisija štetnih plinova u okolinu je najmanja.*

Ključne riječi: *prirodni plin, bioplin, drvna sječka, peleti, ekstra lako loživo ulje, najpovoljniji energent.*

1. INTRODUCTION

The cost–efficiency and sustainability of a production plant is significantly influenced by the consumption and price of thermal energy. The selection of drive fuel and the technical solution of a thermal power plant and installations are integral parts of investments, the assessment of the long-term profitability and business competitiveness. In the last fifteen years the price of natural gas and heating oil has increased around three times, and in some countries by up to five times. By comparing and analyzing available conventional and renewable energy generating products for each case separately, a contribution is made to the correct selection of energy generating products and/or the combination of energy generating products for the purpose of rational production of thermal energy and its optimal proportion in the final product. At plants with a significant proportion of thermal energy in the technological process, the effects of changes in drive fuel price on production costs should be as slight as possible [1, 2, 3, 4].

2. PRODUCTION PLANT

A production plant for processing fruit and vegetables was considered. For its technological needs, heating and preparation of consumable hot water it maximally spends around Q = 1.4 MWh of thermal energy during its year-long operation equaling around t = 7500 hours. For the preparation of consumable hot water around Q_{CHW} = 200 kWh is required. The production plant is located in the area of continental Croatia, where the external air temperature amounts to ϑ_w = – 18 °C in winter, and ϑ_s =

+ 32 °C in summer. The source of thermal energy is hot water with the temperature work mode amounting to ϑ_1 / ϑ_2 = 90 / 70 °C. The available energy generating products for the combustion in a suitable heat generator and transformation into thermal energy are: natural gas, biogas, wood chips, pellets and extra light heating oil. The curve representing the consumption of thermal energy during twelve months is shown in Figure 1.

Figure 1. The consumption of thermal energy throughout the year

3. TECHNICAL AND ECONOMICAL PARAMETERS

3.1 Energy generating products

Energy generating products are means that serve the purpose of energy transformation or constitute an energy form, while fuels are energy sources in various manifestations. Table 1 shows the lower heat of combustion H_d of various drive fuels as well as technical and economical parameters of maximal hourly consumption of thermal energy in the observed production plant [3, 4, 5].

As more than one wood type is used, in practice it is often very hard to precisely determine the heat of combustion of wood chips and/or pellets. Dry wood biomass has the same heat of combustion, around 5 kWh/kg, while its lower heat of combustion varies depending on the amount of moisture. For the evaporation of 1 kg of water from wood mass, around 0.68 kWh of thermal energy is required. For biomass with a defined amount of moisture, the lower heat of combustion is determined according to the following expression:

$$H_d = \left(\frac{\%wood}{100}\cdot 5\right) - \left(\frac{\%moisture}{100}\cdot 0,68\right)\ \frac{kWh}{kg}. \qquad [1]$$

For wood chips with moisture amounting to around 35 % the lower heat of combustion amounts to around H_d = 3 kWh/kg, while for pellets, depending on the wood type, it amounts to H_d = 5 kWh/kg.

Table 1. Technical and economical parameters in using various fuel types (Q = 1.4 MWh)

Energy generatinp roduct	Amount	H_d	ρ	η	Unit price
	V, m³/h	$\frac{kWh}{m^3}$	$\frac{kg}{m^3}$	----	$\frac{€}{m^3}$
Natural gas	167.26	9.3	0.69	0.9	0.366
Biogas	284.27	5.472	1.2	0.9	0.5
	m, kg/h	$\frac{kWh}{kg}$	$\frac{kg}{m^3}$	----	$\frac{€}{kg}$
Wood chips	518.5	3.0	330	0.9	0.0386
Pellets	311.11	5.0	650	0.9	0.24
	V_{elho} l/h	$\frac{kWh}{l}$	$\frac{kg}{m^3}$	----	$\frac{€}{l}$
Extra light heating oil	164.05	10.04	870	0.85	0.877

The average lower heat of combustion of biogas amounts to around $H_{d,bg}$ = 5.472 kWh/m^3. The average consumption of a fuel type is determined according to the expression:

$$V; V_{elho}; m = \frac{Q}{H_d \cdot \eta} \quad \text{m}^3\text{/h; l/h; kg/h}, \qquad [2]$$

where at:

V – hourly amount of natural gas or biogas,

V_{elho} – hourly amount of extra light heating oil,

m – hourly amount of biomass (wood chips, pellets),

η – degree of energy transformation efficiency.

For technological needs, heating and preparation of consumable hot water, the overall annual consumption of thermal energy of a production plant amounts to Q_u = 9177.12 MWh.

3.2 Consumption and price of drive fuel

The quantified consumption values of individual drive fuel types throughout one year are shown in Figure 2. From May to August the consumption of thermal energy for technological needs and preparation of consumable hot water is constant. According to available prices per volume or mass unit of a certain drive fuel type, monthly costs of a certain fuel type for the production of thermal energy during one year are expressed by quantified values shown in Figure 3 [6].

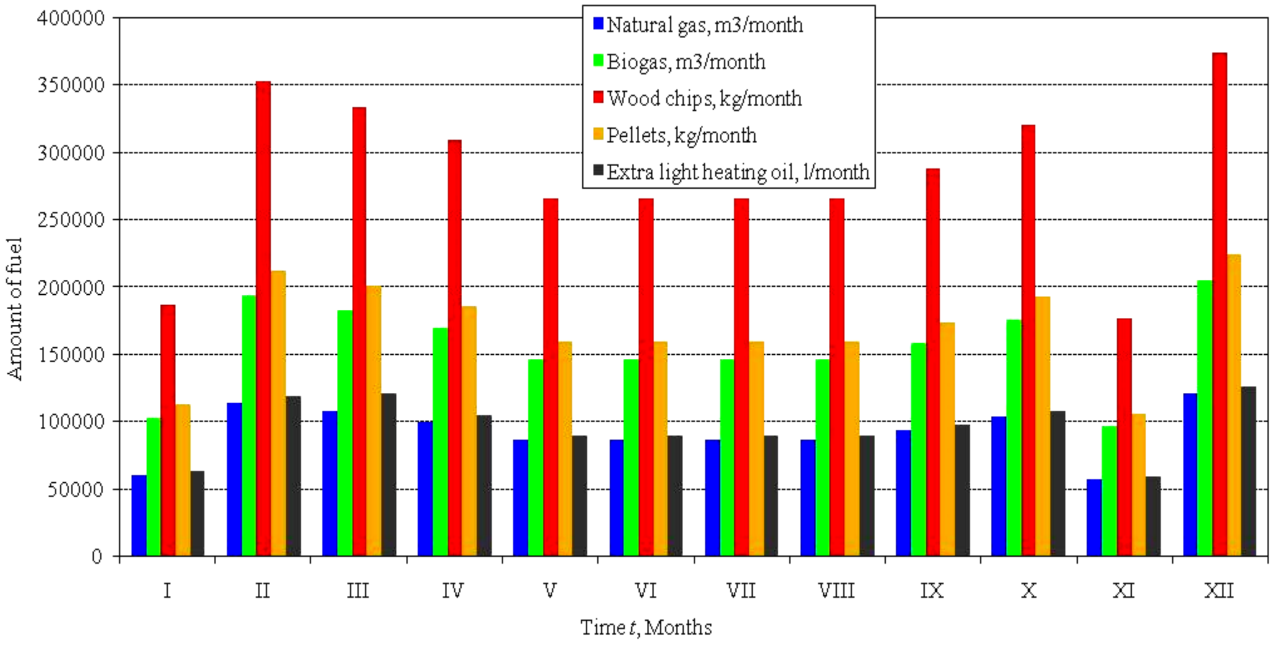

Figure 2. The consumption of various fuel types throughout the year

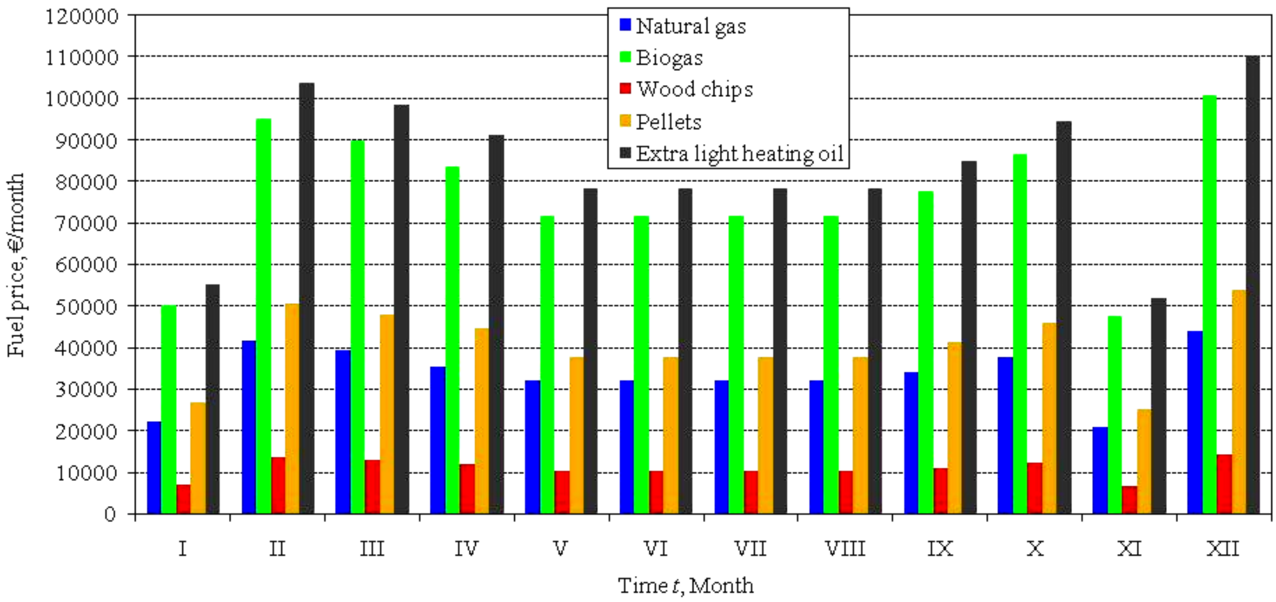

Figure 3. Monthly costs of various fuel types

The unit price of 1 kWh of thermal energy for each fuel type is shown in Figure 4.

Unit prices of 1 kWh of thermal energy generated at a thermal power plant with biomass drive (wood chips with average moisture amounting to around 35 %) are shown including wood chips transportation costs up to 30 km (WC1) and 120 km (WC2) of distance from the production plant.

4. RESULTS ANALYSIS

For the year-long operation of a thermal power plant 3399 tons of wood chips or 1095723 m^3 of natural gas is required as economically comparable in relation to other drive fuel types. The price of 1 kWh of thermal energy obtained by combusting biomass (wood chips) transported up to around 30 km of distance from the production plant amounts to around 0.0146 €, which is around 7.0 – 7.6 times less than the unit price of 1 kWh of thermal energy obtained by combusting biogas or ecologically unfavorable extra light heating oil. By combusting pellets or natural gas the price of 1 kWh of thermal energy increases 3.0 – 3,7 times in comparison with the combustion of wood chips. By preparing and transporting wood chips from the distance of up to 120 km from the warehouse and thermal power plant, the unit price of 1 kWh increases by around 28 % (0.0188

€/kWh), but is significantly lower than the price of 1 kWh of thermal energy generated by the combustion of other drive fuel types. Central and controlled emission of harmful gases is within permitted limits, according to relevant norms [7].

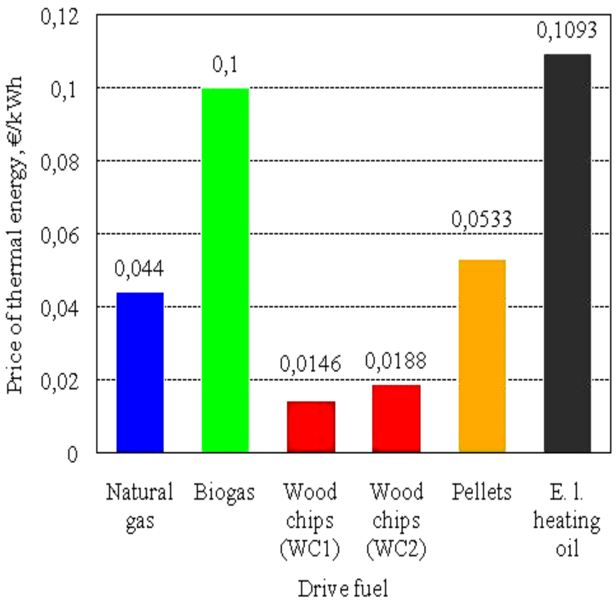

Figure 4. Unit price of 1 kWh of thermal energy for various drive fuel types

Investments in a thermal power plant with a warehouse of wood chips (around 30 days) are around 1.5 – 2.0 times higher if compared with the investment in a thermal power plant for other types of drive fuels. Very small technical adjustments to the plant are required while altering the type of gaseous or liquid drive fuel (natural gas, biogas, extra light heating oil).

5. CONCLUSION

Renewable biomass (wood chips) is a cost-efficient and sustainable drive fuel for the production of thermal energy for the needs of a technological process, heating and preparation of consumable hot water of a production plant. Compared with analyzed fuel types, the investment in a thermal power plant and the stocking of wood chips is around 1.5 – 2.0 times higher. When wood chips are used as drive fuel, the price of 1 kWh of thermal energy is several times lower (3 – 7 times) than the price of 1 kWh of thermal energy obtained by the combustion of other compared drive fuel types. By preparing and transporting wood chips to a distance of up to 120 km from the production plant, the price of 1 kWh of thermal energy increases by around 28 % (from 0.0146 €/kWh to 0.0188 €/kWh), but this does not significantly affect the competitiveness and cost-efficiency of its application if compared with other drive fuel types. The emission of harmful gases into the atmosphere is the lowest.

6. LITERATURE

[1] Jakobović, Z. et al., Tehnički leksikon. Zagreb: Leksikografski zavod Miroslav Krleža, 2007.

[2] A. Čikić, Ž. Kondić: Research of the waste biomass technical and economic value as one of the technological and energy development criteria wood processing plants, Technical Gazzete, Vol 17, 1, University of Osijek, March, 2010, 53 – 59

[3] Radaković, M. Biodizel, biogas, biomasa. Beograd: AGM knjiga, 2009.

[4] Labudović, B. et al., Obnovljivi izvori energije. Zagreb: Energetika marketing, 2002.

[5] Strelec, V. et al., Plinarski priručnik. Zagreb: Energetika marketing, 1995.

[6] http://www.poslovnjak.net/cijene-goriva/luel/ (20th June 2013)

[7] Uredba o graničnim vrijednostima emisija…. NN 21/07 and 10/08, NN RH, Zagreb, 2007 and 2008

Contact:

Ante Čikić, PhD, Assistant Professor
Technical College in Bjelovar
Trg E. Kvaternika 4, 43000 Bjelovar
acikic@vtsbj.hr

Antonio Radić (former student)
Technical College in Bjelovar
Trg E. Kvaternika 4, 43000 Bjelovar
aradic.bj@gmail.com