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ENERGY AND ECONOMIC ANALYSIS OF USING DIFFERENT FUELS FOR HOUSEHOLD HEATING IN SERBIA

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Abstract. *The objective of this study was to create a techno-economic model which purpose would be to perform a techno-economic analysis of the different types of fuels which can be used for heating households in Serbia. Model gives two types of results: the year-by-year cash flow table and comparison diagrams of total costs for different fuels per annual heat consumption (GJ). By comparing total costs for the same heating system but different object size it can be concluded that bigger heating area has lower total costs per GJ and also heating system with boiler has lower values of total costs per GJ then systems with stove(s) for same object size.*
Key words: *Production management, ABC method..*

1. INTRODUCTION

Households in Serbia traditionally utilize solid fuel for producing heat in usually outdated combustion appliances. Also Serbia energy market is specific, in terms of fuel price calculations according to mass (for example coal) or volume (wood) instead of energy content. Furthermore as a country with large areas of agricultural and forested lands, Serbia has strong potential for the production of biomass. Biomass sources represent 63% of the total renewable energy sources (RES). Forests cover about 30% of the territory and approximately 55% is rural area [5]. Unfortunately Serbia households don't use all the benefits of utilization of modern solid biofuels from domestic producer. Based on year 2011 approximately 95% of pellet production in Serbia is exported in Italy and Slovenia, as significant countries for export of this type of products [4]. There are many reasons for poor utilization of solid biofuels in Serbia, especially in households. First, investment costs are relatively high for installation of new types of modern combustion appliances which can be used for new types of fuels. Second, consumer awareness of something new which is not traditional is full of skepticism and fears. Finally, availability of fuel and appliances in Serbian market is not satisfactory, so the consumers have buying more available goods. Standards for quality of solid biofuels and standard for test methods for combustion appliances have been recently adopted in Serbia, toward protecting customers of low quality fuel. However these standards are still not applied in practice.

Therefore, the objective of this study was to create a techno-economic model which purpose would be to perform a techno-economic analysis of the different types of fuels which can be used for heating process in Serbia. Model included evaluation of investment, operational and maintenance costs and considered eight types of fuel (Beech wood, coal "Banovici", briquet, coal "suseni Vreoci", coal "Kolubara", wood pelet, heating oil, natural gas) and was based on real prices from Serbian market in 2015. All the presented data should be used for defining economic aspects for promotion of renewable energy sources in Serbia and to show how households in long term could make savings in segment of producing energy for heating. Techno-economic model gives two types of results that can be beneficial for users, that is the year-by-year cash flow table and comparison diagrams of total costs for different fuels per annual heat consumption (GJ).

2. METHODOLOGY

2.1 Techno-economic analysis

Techno-economic model of different heating systems includes various parameters related to technology and Serbian market and as a result gives the year-by-year cash flow table and basic profitability measure, that is Net Present Value (NPV) [2]. In this study NPV can indicate if the selected heating system and type of fuel with all needed or existed equipment included, is profitable in a long term. How well this type of analysis will

perform in a sense of giving correct and realistic output is directly related to how precise and realistic input is given. This is why adequate determination and prediction of every single input parameter is crucial for model to work properly. Input of techno-economic model of different heating systems includes investment and operating costs, that is, costs of heat supply equipment, additional equipment, equipment installation costs, annual cost of fuel and maintenance and repair costs. Correct estimation of these data was important challenge in this research.

2.2 Establishment of techno-economic model

For eight different types of fuels, namely Beech wood, coal "Banovici", briquet, coal "Vreoci", coal "Kolubara", wood pelet, heating oil and natural gas, following data was defined in order to estimate the heating value of those fuels: upper heating value H_u, moisture content W, ash content A and hydrogen content H. Types of fuels were selected considering two matters. Firstly, which types of fuels are traditionally used in Serbia for heating of households and secondly, which perspective types of fuels have production potential in Serbia.
Data were taken from [3], where they were given as a results of experimental tests.
According to these data, lower heating value H_l was calculated, using following equation [6]:

$$H_l = H_u - 25 * (9 * H + W)$$

Further, on the basis of data about object isolation (which are defined by user), value of required heat power by square meter of heated object was determined.
If object isolation is good, then specific heat flow q equals to 0.08kW/m^2, while if the isolation is poor it equals to 0.135kW/m^2. These values are taken from [7].
Calculated specific heat flow together with the size of object a (which is defined by user) gives required boiler heat output to heat considered household. Following equation is used:

$$P_{req} = a * q$$

According to type of combustion appliance (boiler or stove), using [7], total efficiency η is defined as following. Energy efficiency of boiler η_b is defined according to type of fuel, power of boiler and type of regulation. For solid fuel and boiler up to 50kW with manual regulation, value of 0.68 was taken. For pellet, value of 0.75 was taken from the manufacturer specifications. For heating oil and boiler up to 50kW, value of 0.82 was taken as the middle of given span. For natural gas and boiler up to 100kW with natural draft, value of 0.84 was taken. Energy efficiency of stove η_s was adopted as 0,70 according to stove producer declaration, technical reports of stove testing and literature sources [1].
Ratio of required boiler heat output and total efficiency gives required total amount of energy obtained from fuel:

$$P_f = \frac{P_{req}}{\eta}$$

Ratio of P_{req} and η gives specific fuel consumption m_f:

$$m_f = \frac{P_f}{H_l * a}$$

Taking into account that power plants in Belgrade provide heating from 6 am to 10 pm, sixteen hours are adopted as time of heating t_h.
Using this time, specific amount of fuel m was calculated as follows:

$$m = m_f * t_h$$

Next, total amount of fuel that is spent on defined size of object (in m^2) is calculated with equation:

$$m_a = m * a$$

According to established prices of fuels (FP) and defined number of heating days as 175, annual fuel cost is calculated as:

$$C = FP * m_a * 175$$

Fuel price is determined according to current prices on the Serbian market. Number of heating days is determined as 175 since heating season in Belgrade lasts from 15th of October to 15th of April.
Finally, fuel price per energy unit (per GJ) C_e is calculated with equation:

$$C_e = \frac{C}{H_l * 0.000001}$$

Fuel prices per GJ are used to form comparison diagrams of total costs for different fuels per annual heat consumption.
Within investment costs two possibilities were considered: heating systems with boiler for hot water production and additional equipment for this type of systems (heat panels - radiators, pipes, pumps, etc.) and heating system with stove. When entering the data, user can specify whether within the existing object (household) there are radiators with additional equipment and whether there is a chimney or not. According to these specifications and all other input, investment table is formed. All of the costs are defined for every type of fuel and are shown separately for the boiler and the stove.
Operation costs include annual fuel cost and maintenance costs. Maintenance costs are determined as 3% of equipment costs [8].

2.3 Cash flow table and comparison diagrams

In order to obtain NPV, discounted cash flow analysis is conducted. Discounted cash flow analysis is a method of valuing a project, company, or asset using the concepts of the time value of money. All future cash flows are estimated and discounted by using six percent discount rate. In order to obtain compassion diagrams, it was necessary to express fuel price per energy unit, that is, per GJ. Pervious chapter gives methodology for this. Consequently, all the costs need to be expressed per GJ as well and doing so requires them to be equally distributed in each year. In economic tables this is accomplished with processes of discounting and capitalization [2]. Operation costs take place in each year, but they are of different values, because of inflation. Therefore, calculating equal values in each year involves two steps. First, the present value of operational costs is calculated. Next, that present value is translated into equal values over the 15 years as in the case with investment cost, using PMT function. Now, there are equally distributed investment as well as operational costs in each year and they can be divided with annual consumption of energy (in GJ) in order to be used to form comparison diagrams, together with fuel price per energy unit.

3. DISCUSSION AND RESULTS

Resulting Techno-economic model of different heating systems is in form of excel file with 10 working sheets. First sheet, that is, input sheet, contains drop down menus or type in cells where user within a few steps specifies following information: type of fuel, isolation of object, combustion appliance and size of the house in square meter. According to these data all other required calculations are conducted as described in method section and shown. Interface is user friendly, which means it is very simple to use and to quickly obtain desired results.

Techno-economic model gives two types of results

1) The year-by-year cash flow table.

2) Comparison diagrams of total costs for different fuels per annual heat consumption (GJ).

The year-by-year cash flow table is formed for the specific case defined by user. Diagrams can be utilized by user for specific household in order to compare total cost of heating (investment and operation costs) for different types of fuels. In this way, taking into account availability of fuel as well, it is possible to choose the most cost-effective heating system. For illustration tree diagrams are given. Figure 1 shows investment and operation costs for different types of fuels, stove as combustion appliance, good object isolation, 50m^2, no radiator and existing chimney. Figure 2 shows costs for the same parameters except size of the object, which is 100m^2 in this case. Figure 3 shows costs when boiler is used in 100m^2 object and all other parameters are the same as in the cases before. Finally figure 4 shows costs for boiler and object size of 200m^2.

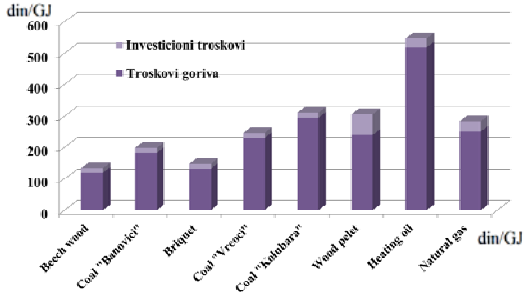

Figure 1 Investment and operation costs for stove and 50m^2

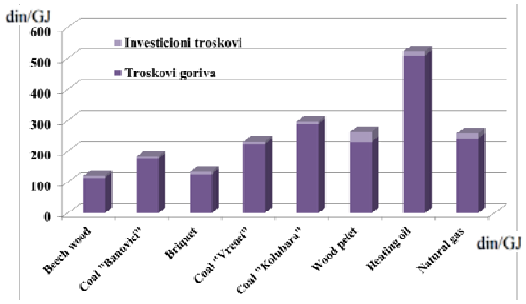

Figure 2 Investment and operation costs for stove and 100m^2

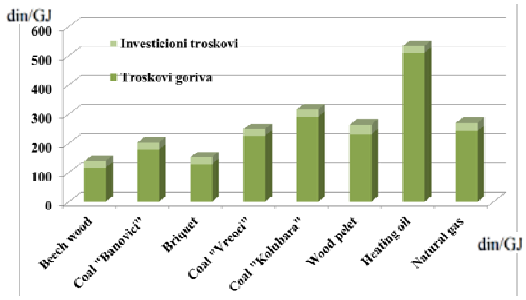

Figure 3 Investment and operation costs for boiler and 100m^2

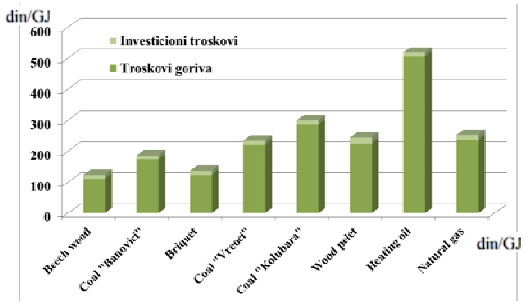

Figure 4 Investment and operation costs for boiler and 200m^2

4. CONCLUSIONS

According to previous presented methodology of techno economic analysis, established techno economic model through software developed in MS

Excell and obtained results for adopted cases which are presented in this paper, following conclusions are made:

- Techno economic analysis for using different fuels for heat production in households in Serbia can be carried out by developed techno economic model software through calculation of total costs per GJ of heat (investment + operational) for different types of fuel commonly used in Serbia households.
- According to results of techno economic model for all discussed cases the lowest costs for heat production in Serbian households are heat systems which used beech wood and wood briquette (more than 100 din/GJ) and the highest cost is the systems with heating oil (more than 500 din/GJ).
- Comparing total costs for the same heating system but different object size (Figures 1 and 2) can be concluded that bigger heating area has lower total costs per GJ and also heating system with boiler which produces hot water for central heating system has lower values of total costs per GJ then systems with stove(s) for same object size (Figures 2 and 4).

Future work on this model will include sensitivity analysis for discussed cases, price adaption for fuels and heating equipment according to market trends and incorporation of cost-benefit comparison for full techno-economic assessment adapt for this region.

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