The comparative analysis of the use of wood waste and natural gas in hot biogenerators from an energetic, economic and ecologic point of view

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Abstract. The paper deals with an energetic, economic and ecologic comparative analysis regarding the installations for the incineration of wood waste in order to ensure the heat for a centralised system used for the supply of thermal energy. The results obtained have highlighted the advantages and disadvantages for each type of fuel used. An aggregate indicator regarding the energetic, economic and environmental effects was conceived in order to obtain a synthetic image concerning the performances of natural gas / wood waste.

1 Introduction

The biomass is considered to be all the animal and vegetal origin products which are used for the production of energy; the biomass represents approximately half (44 – 65%) of the total renewable energy sources used in EU. Biomass, presently provides 4% of the total energy demand of the EU (69 million tons equivalent oil - toe.) . The use of biomass for the generation of thermal energy has to be made in central heating systems rather than individual ones. The EU Member States need to come up with and enforce a National Action Plan in order to regulate the proportion of the energy generated from renewable sources used in transport, as well as for the production of electricity and heat [1].

1.1 The promotion of bioenergy / biomass in Europe and Romania

The European Strategic Framework regarding medium and long term sustainable energy (2020 – 2030 – 2050 horizon) is outlined by a series of documents (strategies, action plans, directives). The development of an energetic European Policy if foreseen built considering three fundamental objectives: s*ustainability* – in order to actively counteract the climacteric

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changes through the promotion of renewable energy and energetic efficiency; *competitiveness* – in order increase the efficiency of the European energetic network through the creation of a real competitive internal market; *supply security* – a better coordination of the energetic supply of the EU and the energetic demand in an international context. An increase of the proportion of the biomass in the energetic mixture up to 150 million t.o.e. could lead to the following benefits: the diversification of the energetic supply of Europe; the significant reduction of greenhouse gases * (209 million tons) [2]
Heating is without any doubt the sector where biomass is used the most, due to simple and not very expensive technologies. Nevertheless, paradoxically speaking, the use of biomass is slowly increasing in this sector [3].

1.2 The promotion and use of bioenergy / biomass at a national level

The European Directive for renewable energy sources establishes for Romania ambitious targets for the year 2020, targets which take into consideration both the potential of renewable sources as well as their capitalisation in the year of reference 2005. Therefore, the national potential assessed by renewable sources (assessment carried out through the National Action Plan for Renewable Energy – NAPRE) is presented in Table 1:

Table 1. Assessed National Potential of Renewable Sources [4].

Renewable Energy Source	Yearly Energetic Potential	Economic equivalent e*nergy* (thousands toe)	Applicability
Solar energy, of which:		1536	
- thermal	$60x10^6$ GJ	1433	Thermal energy
- photovoltaic	1200 GWh	103.2	Thermal energy
Wind energy	23000 GWh	1978	Thermal energy
Hydro Energy, of which:	40000 GWh	3440	Thermal energy
- below 10 MW	6000 GWh	516	Thermal energy
Biomass	$318x10^6$ GJ	7597	Thermal energy
Geothermal energy	$7x10^6$ GJ	167	Thermal energy

The technologies for the generation of heat through direct incineration of wood residues are direct incineration and co-incineration. Direct incineration occurs in special boilers and may be divided in two main categories which are used either for the direct production of heat or for the generation of steam. Co-incineration is the modern practices which allows for the biomass to have a fast and cheap input on the energetic market, it is also the practices for the co-incineration of a fossil fuel (generally coal) with raw material from biomass. Co-incineration has a number of advantages, especially where the output is represented by the generation of electricity [5].

Taking into account the direct co-incineration, the adequately prepared biomass is fed directly into the coal boiler. Indirect incineration implies the separate gasification of biomass in order to produce a fuel gas with a decreased heating power, which is then burnt in the burning chamber of the coal. Taking into account the parallel co-incineration, the biomass is burnt in a separate boiler while the steam resulted is fed into a burning system of the coal where its temperature and pressure are increased.

1.3 The energetic assessment of biomass and capitalisation solutions in Jiu Valley

The energetic potential of the biomass for Jiu Valley is estimated to 750 TJ (forest vegetal biomass) and 30 TJ (biogas).

The biomass categories capitalised in Jiu Valley are: forest vegetal biomass; biogas resulted from waste water treatment; urban waste [6].

A specific aspect of the area, together with abusive deforestations is constituted by the abandonment of the inappropriate trees and the discharge of the wood waste into the rivers and into inadequate spaces. Therefore the capitalisation of the biomass paradoxically contributes to the reduction of the environmental impact [7].

The technologies with the greatest interest are presented in the Table 2: direct incineration in the boilers; advanced thermal conversion of the biomass into a secondary fuel through gasification or pyrolysis followed by the use of the fuel by an engine or by a turbine; biologic conversion into methane through aerobic bacteria digestion; chemical and biochemical conversion of organic matter into hydrogen, methanol, ethanol, or diesel fuel; combined incineration: direct and indirect co-incineration; parallel co-incineration; energetic plantations on slag heaps.

Table 2. Actual applications for the energetic potential of the biomass (including wood waste) [8].

Process	Output	Applications	
Combustion	Hot gases	boiler steam engine	heating up spaces, process heat hot water, electricity / heat
Gasification	Fuel gas	boiler, gas engine gas turbine combustion cells	heat electricity / heat
	Synthesis gas	synthetic gas, liquid fuel, chemicals	heat transport
Pyrolysis	Fuel gas Liquid fuel Solid fuel	engine, boiler engine	electricity / heat electricity / heat transport

2 Case study

In order to carry out the assessment of the energetic, economic and ecologic performances for the production of heat using biogas / wood waste fed generators, a hot water generating study was taken into consideration for an installed heating power of 1 MW_t . The annual number of operating hours varies between 1000 and 4000 hours. The following emission factor was taken into consideration CO_2 0.202 kg CO_2/MWh [9-10]. Based on the relations in the specific literature, we calculated: annual consumption of gas and wood waste, energy actually delivered on gas and wood waste, annual cost of gas consumed and annual cost of wood waste consumed, impact CO_2 gas.

The primary calculation data are brought forward synthetically in Table 3 and are graphically presented in Figure 1.

Table 3. Specific economic and energetic characteristics for natural gas and wood waste

Specific economic and energetic characteristics for natural gas and wood waste	gas	wood waste
The price of 1 kWh thermal energy [lei]	0.128	0.025
The price of 1 m^3 [lei] and of 1 kg of wood [lei]	1.35	0.085
The energetic equivalent of 1 m^3 of gas [kWh] and 1 kg of wood waste [kWh]	10.57	3.372
Energetic efficiency	0.9	0.831
Real delivered energy for 1 m^3 of gas [kWh] and 1 kg of wood waste [kWh]	9.51	2.80

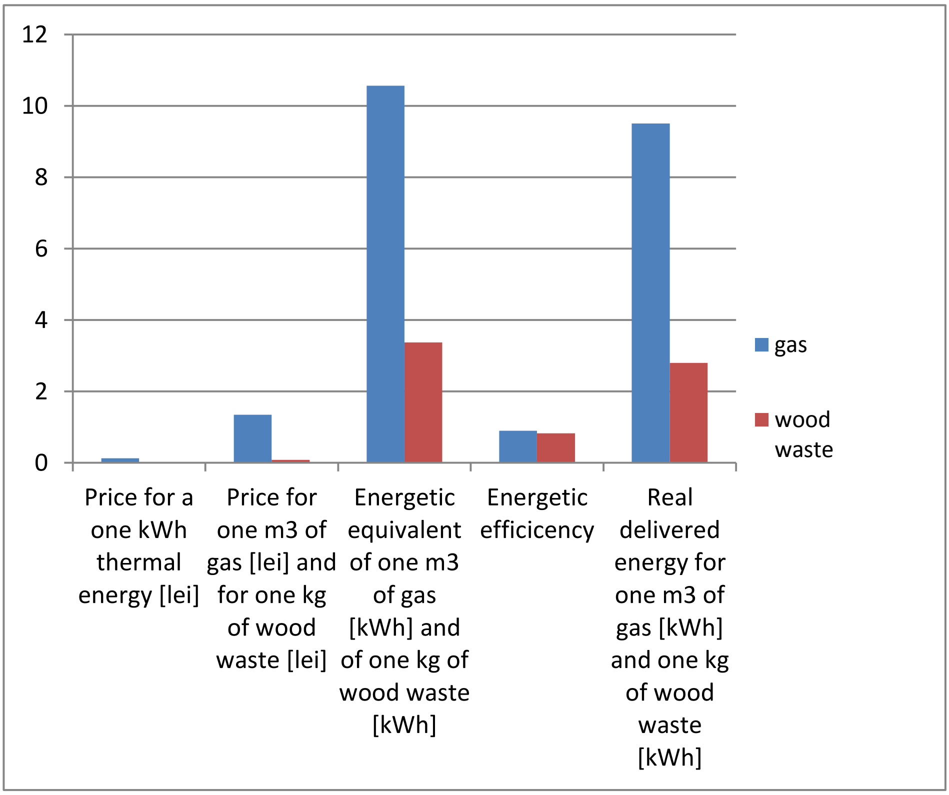

Fig. 1. Specific economic and energetic characteristics for natural gas and wood waste

3 Results and discussions

Based on the results in Table 1, considering different yearly operation periods, the consumption of natural gas respectively biomass were calculated. The graphic representation of results is presented in Figure 2. The differences expressed in percentages between the variation of the use of natural gas and the variation of the use of biomass are highlighted based on Figure 2. The difference in quantity between the wood waste consumption and the natural gas consumption increases depending on the number of operation hours of the hot water thermal generator. The average increase of the consumption of biomass compared to the consumption of natural gas amounts to 70.56%. The increase percentage mentioned previously is due to the fact that the energetic equivalent of wood waste is 31.90% of the energetic equivalent of natural gas, while the heat generator efficiency supplied with wood waste represents 92.31 % of the efficiency corresponding to gas supply. Summing up the two percentages, it results 24.44% representing the reduction of the energetic performance of the use of wood waste in relation to the natural gas. 29.44% is found in most of the consumption of wood waste compared to the natural gas – 100 % - 29.44 % = 70.56 %. Taking into account the thermal efficiencies for the use of gas respectively wood waste the real capitalised energies were determined for different periods of operation.

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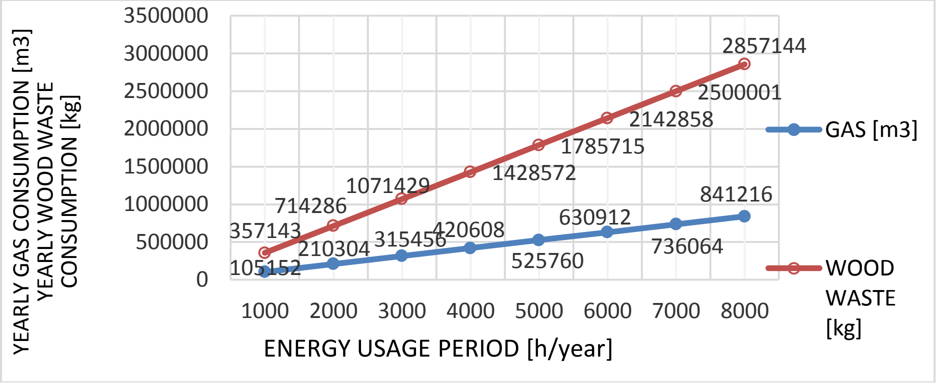

Fig. 2. Yearly variation of fuel use

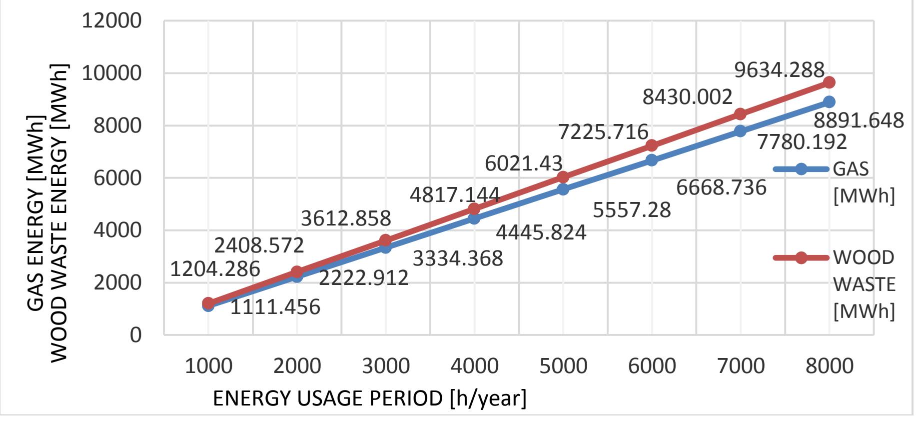

Fig. 3. Yearly variation of energy used

Analysing figure 3 it may be observed that the primary energy used considering wood waste is 7.71 % higher than the use of natural gas due to the difference of percentage between the efficiency of the thermal generator fuelled by natural gas and the efficiency of the wood waste generator. Based on the unit prices of natural gas / wood waste and their consumption, depending on the yearly usage period of energy the diagram in figure 4 was developed.

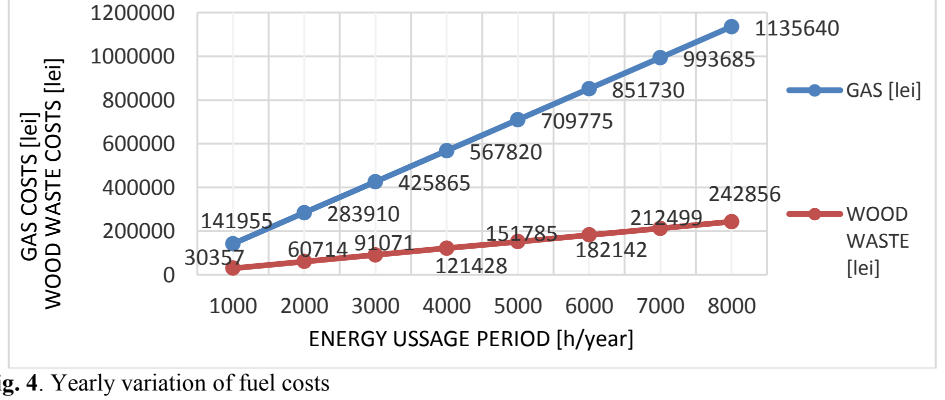

Fig. 4. Yearly variation of fuel costs

Analysing Figure 4 it is observed that the difference between the costs of natural gas and the costs of wood waste is 78.62 %, value which is sums up the price, heating power, and energetic efficiency differences.
The statements in the speciality literature mention the fact that if the CO2 consumption of the chlorophyllian assimilation is balanced with the CO2 emission of the wood incineration the carbon footprint for the biomass is 0. Therefore, Figure 5 brings forward the yearly variation of the carbon footprint of natural gas.

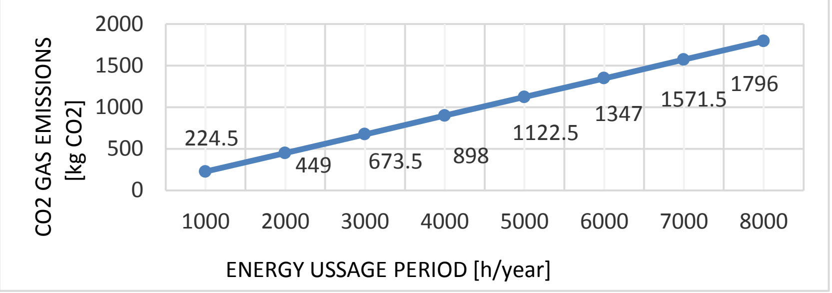

Fig. 5. Yearly variation of CO_2 emissions

Summing up the unit price of the gas and that of the wood wastes with the unit price of 1 kWh for gas and wood waste the price of 0.27 lei/kWh results for gas and 0.051 lei/kWh for wood waste. Comparing the unit prices above it is observed that the cumulative price for wood waste is smaller with 81% than the price of gas. Taking into consideration the energetic equivalent of gas / wood waste it is observed that the natural gas has an energetic efficiency with 68% higher. Introducing the convention that the higher percentage is more favourable and the difference from 100% if more disadvantageous based on the radar diagram in Figure 6 and Table 4was developed.

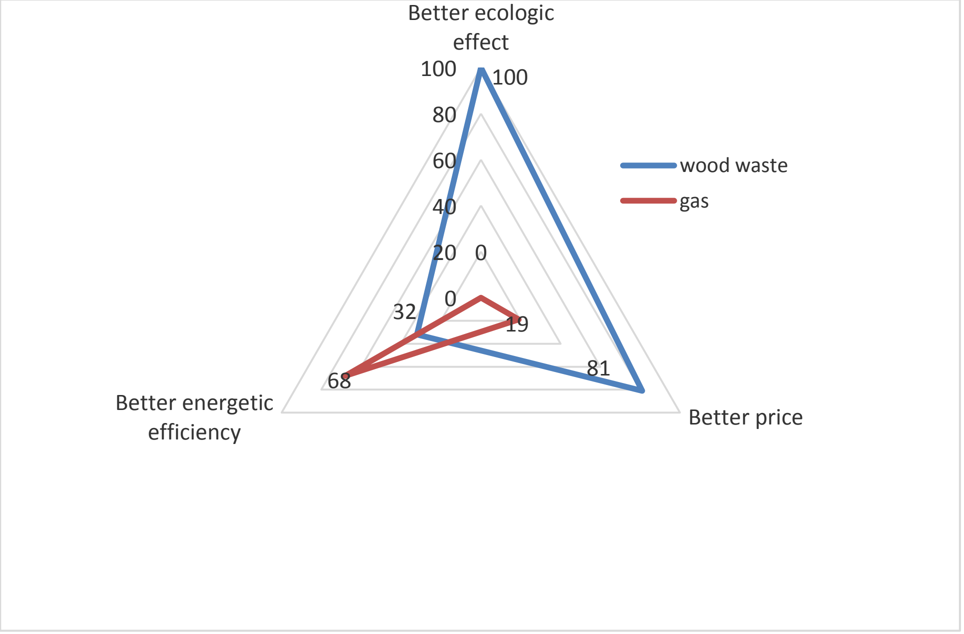

Fig. 6. Diagram for the determination of the cumulative energetic-economic-ecologic effect

Table 4. Visual values for the ecologic, economic and energetic effects.

Indicators	Wood waste	Gas
Better ecologic effect	100	0
Better price	81	19
Better energetic efficiency	32	68

Calculating the area of the surfaces: the total S_t, of the wood waste S_{wood} and of the area of the gas S_{gas}, and developing reports between the total surface and the surfaces of the fuels, the following results are obtained: $S_t/S_{wood} = 2.127$, respectively $S_t/S_{gas} = 22.471$. Based on the results it may state that the cumulated beneficial effect of the use of wood waste is 10.44 times better than the cumulated effect of the gas.

4 Conclusions

Taking into account the results obtained within the case study the following conclusions may be drawn:

1. The yearly consumption of wood waste is superior to the consumption of natural gas, the difference increasing as the yearly heat use schedule increases;
2. The energy used is sensibly larger for wood waste than for the natural gas due to the thermal efficiency differences of the hot water generators;
3. The costs for wood waste are smaller than for gas given the fact that the price unit for gas is 5 times higher than the price unit for wood waste.
4. Taking into account the greenhouse gasses, the use of wood waste is clearly more profitable.

Based on the aggregation method proposed by the authors, the conclusion that the use of wood residues leads to a performance aggregate coefficient of approximately 10 times greater than that of natural gas was drawn.

References

1. D. Pasculescu, L. Pana, V. M. Pasculescu, F. Deliu, Mining of Mineral Deposits, **13** (2), 1-16 (2019).
2. European Directive for Renewable Energy (2009/28/EC).
3. G. Buica, A. E. Antonov, C. Beiu, D. Pasculescu, R. Dobra, Quality-Access to Success, **18**, (S1), 35-40, (2017).
4. The national action plan for renewable energy PNAER,
5. I. Dosa, *National Conference of Thermodynamics with International Participation*, Romania, **1(**1S), 4-17, (2011).
6. I. Dumitrescu, B. Cozma, B. Gh. Urdea, *Proceedings of the 15th International Multidisciplinary Scientific Geoconference SGEM 2015, Exploration and Mining*, **3**, 603-610, (2015).
7. V. A. Florea, *Proceedings of the 16th International Multidisciplinary Scientific Geoconference SGEM 2016*, **2**, 719÷725, (2016).
8. Romania's energetic strategy for (2007-2020).
9. Transit paper - Energy Roadmap 2050 (2011).
10. The National Action Plan for Efficient Energetics (2007-2010).