Does the Combustion of Biomass Increase the Efficiency of Heating Companies? Evidence from Slovakia

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Over the last decade, the consumption of renewable energy within the EU increased by 66%, and corporations have recognized that heating with wood waste is a cost-effective response to fluctuating fuel prices and a means of avoiding waste disposal costs. The main objective of this paper was to determine whether the combustion of biomass compared with the use of fossil fuels as the primary heat source would increase the efficiency in Slovak heating companies. This research was evaluated *via* methods of synthesis, analyses, and financial analyses. The survey found that heating companies with combined productions had better economic results. Based on the peer group comparison, heating companies using renewable resources achieved remarkably higher performance indicators. Among renewable energy sources, total biomass plays an important role and accounted for just over two thirds (64%) of the gross inland energy consumption of renewables in the EU. Wood pellets and agglomerates are currently the most economical way of converting biomass into fuel and are a fast-growing source of energy in Europe. The economic efficiency and key performance indicators strongly depend on the input prices of the energy carriers. In the last decade, the cost of heat produced from natural gas amounted on average to two to three times the cost of deciduous wood. Biomass production can generate employment, and if intensive agriculture is replaced by less intensively managed energy crops, there are likely to be environmental benefits, such as reduced leaching of fertilizers and reduced use of pesticides.

Keywords: Biobased economy; Biomass combustion; Heating companies

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INTRODUCTION

The European Commission has set a long-term goal to develop a competitive, resource efficient and low carbon economy. To reflect the setup trend, governments have introduced a new legislation in order to support the transition towards bioeconomy with the aim to reduce the global dependence on the fossil fuel resources. However, socio-economic research on the transition towards a bioeconomy on a corporate-level remains scarce. Van Lanckera *et al.* (2016) presented a study in which the basic characteristics of innovation processes and influencing factors specific to a bioeconomy context were identified. The transition toward a bioeconomy will rely on the advancement in technology of a range of processes and the achievement of a breakthrough in terms of technical performances and cost effectiveness. Also it will depend on the availability of sustainable biomass.

Literature Review

Biomass as an energy source that contributes to a decreased dependence on imported fossil fuels, while at the same time, adding value to countries where biomass fuel sources thrive and providing a source of renewable energy. Several studies have been devoted to biomass combustion and the use of renewable energy sources. The study by Lund *et al.* (2016) confirmed that the technologies used for converting biomass to fuels, heat, and electricity are continuously developing and can be expected to change the production and use of bioenergy products. In particular, there are emerging options for converting lignocellulosic biomass into refined solid, liquid, and gaseous fuels, which allows access to new feedstock resources. Dornburg and Faaij (2001) analysed different biomass energy systems regarding their energetic and economic performance related to primary fossil fuel energy savings. It was concluded that the performance of systems can be expressed as a function of scale. This is done by applying generic functions to describe the efficiencies and specific investment costs of plants, as well as by expressing costs and energy use of logistics and heat distribution as a function of conversion unit capacities. Scale effects within biomass energy systems are remarkable. This was confirmed by several other studies (Balat *et al.* 2006; Demirbas *et al.* 2009; Jahirul *et al*. 2012).

The number of new small- and medium-scale biomass combustion units shows that the solid fuel boiler market is continuously increasing across Europe. According to the study by Mígues *et al.* (2012), which studied the importance of wood pellets, chips, and wood logs for small- and medium-scale heat production, pellet use can contribute substantially to reaching the renewable heat and electricity goals set by the European Union (EU). For an example, the study of Ericsson and Werner (2016) confirmed the expansion of usage of biomass in the Swedish district heating systems; however, the conditions for biomass were supported by the government investment subsidies. The expansion of biomass use in a district heating systems depends also on the natural resources, skills and structure in the forest industry, national energy policy tools, and biomass price volatility.

Saidur *et al.* (2009) analysed several aspects that are associated with burning biomass in boilers, estimating the higher heating value of biomass, comparison between biomass and other fuels, combustion of biomass, and co-firing of biomass and coal. They found out that utilizing biomass in boilers offers many economic, social, and environmental benefits such as financial net saving, conservation of fossil fuel resources, job opportunities creation and emissions reduction.

Another aspect that needs to be taken into consideration is connected with emissions. Biomass is considered to be CO_2 neutral, and the NO emissions from straw and wood combustion are only approximately one third or one half of that from coal combustion. Moreover, increasing the biomass co-firing ratio reduces NO emissions, and increases the combustion efficiency (Wang *et al.* 2015). When harvested from the field or forest, biomass materials are not a pure mix of carbon, hydrogen, and oxygen (C, H, and O), but they also contain N, P, K, S, and Cl, as well as many trace elements that are essential to maintaining the metabolism, respiration, and growth of living plants. These additional chemical elements present challenges to combustion engineering technology in the form of fouling, deposition, slagging, and corrosion of the internal burner structure and heat transfer surfaces (Lou *et al.* 2016). The emission of metals and other elements to the air and soil may also have environmental impacts. Depending on the quality of the combustion process and investment in emission controls, the use of biomass fuels can be as clean as natural gas utilization or even dirtier than coal (Duval 2001; Sims and Bassam 2004). The study of Khan *et al.* (2009) indicated that among alternative energy sources, the biomass is the only carbon-based sustainable option and presents the major issues concerned with biomass combustion with special reference to the small scale fluidized bed systems. They conclude, that even a range of concerns with biomass exists, but none of these issues represents an insurmountable obstacle for this sustainable energy source.

In a more recent study, Khodaei *et al.* (2017) researched the effect of air staging on the gaseous and particulate emissions and temperature. Two different secondary air distribution modules were employed at two different axial positions from the bed surface in a 15-kW fixed-bed laboratory-scale combustion system that included a grate and underfeed bed stocker. The effects of air staging on the temperature, burning rate, and gaseous and particulate emissions were assessed over a selected primary air flow rate and a range of secondary air flow rates. The secondary air inlet module with a uniform distribution of air resulted in a 50% CO reduction by shifting the combustion to a more fuel lean environment and high-temperature post-combustion zone.

Other important characteristics are related to the ashes derived from the combustion of biomass, with the chemical transformations at high temperatures and its effect on the combustion equipment being particularly important. The study by Nunes *et al.* (2016) outlined the necessity of knowing the chemical composition and physical properties of ashes, and with that knowledge it is possible to predict the tendency for the formation of deposits in the boiler components, as well as their potential to cause corrosion, erosion, and abrasion. The behaviour of the ashes in the system is highly dependent on the fuel, particularly when it comes from industrial waste and energy crops (Yao *et al.* 2017).

This paper investigated the direct combustion of biomass for the purpose of heat processing in Slovakian heating companies, where biomass resources are generally available on site and burned in conventional gasification boilers. The aim of the survey was to compare the efficiency of biomass combustion with that of fossil fuel as a primary heating source for the studied heating companies. There has been published several research studies on the topic of biomass combustion, but there is no study focused directly on the comparison of biomass and fossil fuel combustion. The novelty of this paper is that it provides a comprehensive comparison of the efficiency of biomass versus fossil fuels combustion on the example of the heating companies in Slovakia and is a practical demonstration of the current trend in increasing the use of biomass for heat generation.

EXPERIMENTAL

Materials

The research methodology consisted of three phases. In the first phase, methods of synthesis, analyses, and summary were used, and a short review was prepared. In the second phase, according to the Decree of the Office for Regulation of Network Industries, the heat production efficiency of two companies was analysed and compared. The first company used only gas as a primary source, while the second one used mainly biomass (it is considered 100% biomass). In the third phase, peer group analyses were conducted, which included two groups of heating companies; Group A represented companies producing heat via combined production from gas and renewable resources, which was mainly biomass, while Group B uses gas as the primary source. To evaluate the results of the research, financial analysis tools were used.

Data collection

Heating companies in Slovakia were the subject of this research. The objective of this research was the comparison of the efficiency of biomass combustion and gas combustion. The primary data was collected *via* a study internship at two medium-sized heating companies, Company A (Výroba Tepla, Slovak Republic) and Company B (Liptovská, Slovak Republic), which were used in the second phase of this research. The core part of this research was devoted to the structure of the heating system, boiler parameters, and calculation of the fixed and variable costs. Finally, the economic efficiency of both analysed companies was evaluated and they were compared.

Sample size

The sample for the second phase consisted of two groups of companies. The aim was to compare the efficiencies of a heating company that uses 100% gas as a primary source and a company that uses 100% biomass as a primary source for heat generation. A heating company is understood to mean a company whose main activity is the production, supply, and distribution of heat, whereby heat is produced by one or more separate heat sources. Generated heat output serves to provide heat demand (heating and hot water supply) through a heat distribution network which is designed for all types of clients, *i.e.*, households, companies, public buildings. The deep analysis of the selected companies created a knowledge base for the third phase. The sample in the third phase was composed of ten randomly selected Slovak heating companies, which were divided into two groups. Group A represented companies producing heat *via* combined production from gas and renewable resources, which was mainly biomass, while Group B uses gas as the primary source. The research data was collected from 10 out of the 102 heating companies associated with the Slovak heating industry. The financial statements of the analysed companies were extracted from the registry of financial statements managed by the Ministry of Finance of the Slovak Republic. On the basis of Slovak legislation, which determines the eligible and ineligible costs of heat production and regulates the maximum level of reasonable profit, it was concluded that the sample size was sufficient.

Methods

Evaluation of the research

In the first part, the survey data were evaluated based on descriptive and graphical analyses. The focus was devoted on the current renewable energy trends in Europe and in Slovakia.

In the second part, the method of calculation of the heat price, according to the Decree of the Office for Regulation of Network Industries, was used. Revenues from heat sales are affected by the price and quantity of the heat sold. The heat price is regulated by the state and determined by the cost items of heat production, including eligible and ineligible costs. The derivation of equations 1-8 are defined by the Decree of the Office for Regulation of Network Industries. The heat price comes from two components, which are fixed and variable factors. Economically justified variable costs include variable costs for the purchase of fuel and buying a maximum amount of heat determined by energy efficiency indicators. They are calculated with the following equation,

$$N_{EOP} = N_U + 0.5\ (N_N - N_U) \tag{1}$$

where N_{EOP} is the annual economic eligible costs in a variable part of the heating price (€), N_U is the annual cost invoiced by the supplier of fuel or heat (€), and N_N is the annual cost of buying fuel or the purchase of heat determined by the energy efficiency indicators (€).

Other variable costs include transport fuels, electricity, water technology, materials technology, removal and disposal of ash, and buying of emission allowances.

The maximum price of biomass (including correction coefficients) is determined by the decree controller (state regulator) with the following equations.

The natural gas price (€/kWh) is determined by,

$$C_{\text{natural gas}} = 1.15 \times CE_{\text{NCGt}} \tag{2}$$

where CE_{NCGt} is the average of the daily rates published by the European Energy Exchange on its website for the product NCG Natural Gas Futures Year Cal-T over the previous 12 months before sending the request for a heating price.

The price of wood and chips per year in tons (€/kWh) is determined by,

$$C_{\text{chips}} = 0.019 \times k_a \tag{3}$$

where k_a is the correction coefficient.

The price of pellets (briquettes) per year in tons (€/kWh) is determined by,

$$C_{\text{pellets}} = 0.038 \times k_b \tag{4}$$

where k_b is the correction coefficient.

The price of agricultural biomass per year in tons (€/kWh) is determined by,

$$C_{\text{agricultural biomass}} = 0.023 \times k_c \tag{5}$$

where k_c is the correction coefficient.

The maximum amount of the total eligible cost of the fixed costs in the price proposal by the regulated entity in year *t* is calculated according to the formula,

$$MFN_t = MFN_{t-n} \times \left[1 + \frac{\left(JPI - X \times \frac{OT_{t-n}}{OT_t} \right)}{100} \right] + \mathrm{Y} \tag{6}$$

where MFN_t is the maximum eligible cost for the fixed costs (€) other than the purchase of heat for production, distribution, and supply of heat for year *t* without reasonable profit, *JPI* is the arithmetic average of the core inflation for the period from July of year *t*-2 to June 1 of year *t*-1 published by the Statistical Office of the Slovak Republic, *X* is the efficiency factor for the use of the cost of production, distribution, and supply of heat (the value for the regulatory period is 3.50%), OT_t is the assumption of the regulatory amortization related to the regulated activities in year *t*, OT_{t-n} is the regulatory depreciation related to the regulated activities in year *t*-n that have been applied in an approved price decision in year *t*-n, and *Y* is the factor of the investment development of thermal energy, which takes into account the cost in year *t* for modernization, reconstruction, and construction of new thermal equipment. Then, *Y* is calculated by the following formula,

$$\mathrm{Y} = \frac{(\mathrm{IN_{av}} \times 0.04) + (\mathrm{IN_{ad}} \times 0.033)}{\mathrm{MFN_{t-n}}} \tag{7}$$

where IN_{av} is the cost (€) of modernization, restructuring, greening, and construction of the heat, and IN_{ad} is the cost (€) of modernization, reconstruction, and construction of the heat distribution.

The reasonable profit in the price of heat is determined by multiplying values of the regulatory asset base (RAB) and real rate of return on the regulatory asset base (WACC), while the maximum amount of the reasonable profit may not exceed 20 €/kW of the total regulatory input sampling device (RP). The RAB is the value of the assets serving to perform regulated activities, which is determined as the sum of net book value of the tangible and intangible assets and rented assets, and the WACC is determined by the regulator at a fixed amount of 6.47%.

The RP with heat consumption for heating and heat consumption of domestic hot water for year *t* is calculated with the following formula,

$$RP = \frac{Q_{t-2}}{5300} \times \frac{3564}{{}^{o}D_{t-2}} \tag{8}$$

where $Q_{t\text{-}2}$ is the actual amount of heat delivered in the year *t*-2 (kWh), the number 5300 represent a yearly recognised number of hours of heat production and $°D_{t\text{-}2}$ is the average number of degree days in year *t*-2, which is published on the Regulatory Office website. The average number of degree days is a function of the number of heating days in year *t*-2, indoor heating room temperature (20 ° C), and outside air temperature.

In the third part, the survey data was evaluated based on and financial analyses and peer group comparison. As Musa *et al.* (2015) noted, the information pertaining to the financial statements is of great importance, and through which interpretation and analysis were conducted. It was through the process of financial analysis that the key performance indicators, such as the liquidity solvency, profitability, and efficiency of operations of a business entity, may be ascertained. Meanwhile, the short- and long-term prospects of a business were also evaluated. When selecting the performance indicators, the recommendations from the research conducted by Riedl and Srinivasan (2010) were used as the basis. Three key performance indicators were selected, which were the return on equity (ROE), RETURN on REVENUES, and EBITDA (earnings before interest, taxes, depreciation, and amortization) share on REVENUES. To avoid inaccuracy and deviation in the results caused by the numbers from one year, two consecutive years based on the official end-year numbers were analysed.

RENEWABLE ENERGY REVIEW

Renewable Energy Trends in Europe

The EU has close to 182 million hectares (ha) of forests and other wooded land, which corresponds to 43% of the total EU land area. There is great diversity of natural forest types, cover, and ownership structures in the EU. Additionally, the extent of forested areas varies considerably. Finland, Sweden, and Slovenia are covered 60% by forests, while the amount of forests in the Netherlands and United Kingdom is only 11% (Eurostat 2017a). As a result of afforestation programs and natural regeneration on marginal lands, the forest cover in the EU has increased over the past few decades.

Among the EU member states, Sweden produced the most roundwood (70 million m^3) in 2014, followed by Finland, Germany, and France (each producing between 52 million m^3 and 57 million m^3). Slightly more than one fifth of the roundwood production in the EU in 2014 was used as wood fuel, while the remainder was industrial roundwood that was used either for sawnwood and veneers, or pulp and paper production. The overall level of roundwood production in the EU reached an estimated 425 million m^3 in 2014 (Eurostat 2017b).

Between 2005 and 2014, the consumption of renewable energy within the EU increased 66%. Among renewable energy sources, total biomass (wood and other biomass, including municipal waste) plays an important role and accounted for just over two thirds (64%) of the gross inland energy consumption of renewables in the EU in 2014. As a part of this biomass total, wood and agglomerated wood products, such as pellets and briquettes, provide the highest amount of energy from organic, non-fossil fuel materials of biological origin and accounted for almost half (45%) of the gross inland energy consumption of renewables in the EU in 2014 (Renewable Energy Policy Network 2016).

The wood-based industries in the EU cover a range of downstream activities, including the woodworking, large parts of the furniture, pulp and paper manufacturing and converting, and printing industries. Together, around 432,000 enterprises were active in wood-based industries across the EU. The economic weight of the wood-based industries in the EU as measured by the gross value added was equivalent to 129 billion EUR or 7.9% of the manufacturing total in 2013. Wood-based industries employed 3.3 million people across the EU in 2013, or 11.1% of the manufacturing total (European Commission 2013).

Forests are one of the most important renewable resources in Europe and provide multiple benefits to society and the economy. They are one of the main sources of biodiversity in Europe. Energy supply has always been one of the main uses for wood. Policy interest in energy security and renewable sources of energy, combined with relatively high oil and gas prices, has led to a reassessment of the possible use of wood as an energy source in recent years. The use of renewables is ensured by legally binding targets that have been set for each EU member state through to 2020. This goal was designed to help reduce emissions, improve the security of energy supplies, and reduce dependence on energy imports. The new Forest Strategy identifies the key principles needed to strengthen sustainable forest management and improve competitiveness and job creation, in rural areas in particular, while ensuring forest protection and delivery of ecosystem services. The Forest Strategy also specifies how the EU wishes to implement forest-related policies.

Renewable Energy in Slovakia

Forests form an important part of the environment in the Slovak Republic. In 2016 there were 2.01 million ha of forest land resources, which means the forest coverage in Slovakia is approximately 41% of the total land. The percent of economic, protection, and special forests amount to 71%, 17%, and 12%, respectively.

The species composition of forest stands in Slovakia is very diverse. The growing biological diversity positively affects the stability of forests. Coniferous stands, leafy stands, mixed grasses, and hollows cover 30.5%, 49.9%, 19%, and 0.6% of the total forest area, respectively. The two most prevalent trees are beech at 31.2% and spruce at 25.9% of the total forest land. Forest stock has grown steadily and reached 475 million m^3 in 2016. This increase in inventory is mainly because of a high proportion of 60-year- to 100-year-old stands, the changing inventory calculation methodology, and application of new growth tables. The average supply per ha is 243 m^3. Over the last five years, yearly mining has oscillated between 6.6 million m^3 and 10 million m^3, and the yearly supply of roundwood is 8.2 thousand m^3 on average.

Biomass is a renewable energy source with the highest technical potential in Slovakia and is presently the second most useable energy source. The percent of renewable energy sources used to produce electricity, and supplied in 2016 in Slovakia, amounted to 21% of the total, which was the highest percent of the biomass used (Fig 1a). Within the renewable energy sources' structure (Fig. 1b), biomass is up to 78% of total renewable energy, solar energy is 15%, water is 6%, and wind is 1%.

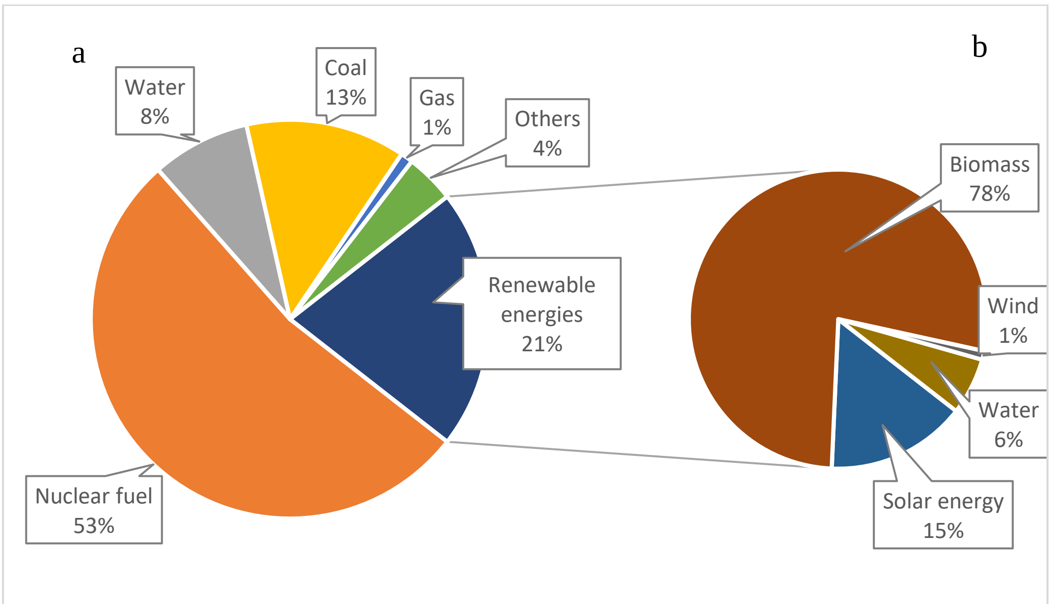

Fig. 1. Primary energy sources in Slovakia in 2016: a) total structure of primary energy sources in Slovakia, where the renewable energy sources are 21%; and b) structure within the renewable energy sources

The annual useful potential of renewable energy sources in Slovakia amounts to 96,800 TJ/year (26,900 GWh/year). The total potential, including large hydropower plants, amounts to 117,000 TJ/year (32,000 GWh/year). In the near future, the total potential of wood biomass resources could increase, if biomass from forest plantations and foreseen increased extraction was used. The percent of wood biomass can be increased by the use of municipal waste from park modifications, urban greenery, *etc*., which represents 300 thousand tons per year. The establishment of energy crops can add an additional 440 thousand tons per year. By 2020, the potential of wood biomass may range from 2520 thousand tons to 2720 thousand tons per year. The Table 1 shows an overview of the total technically exploitable renewable energy potential in Slovakia, and includes the production of heat and electricity (Fáber 2012).

Table 1. Potential of Renewable Energy Sources in Slovakia

Type of Renewable Energy / Technically Exploitable Potential	GWh/year	TJ/year
Geothermal energy	6,300	22,700
Wind energy	605	2,180
Solar energy	5,200	18,700
Small hydropower plants	1,030	3,720
Hydropower plants > 10 MWe	5,570	20,060
Biogas	25,00	9,000
Biomass	11,200	40,500
Total (excluding hydropower plants > 10 MWe)	26,900	96,700
Total	32,500	117,000

Biomass energy has a value of 40,500 TJ/year (11200 GWh/year), which accounted for 35% of the total renewable energy. For energy purposes, it is possible to use forest biomass, including energy crops, agricultural biomass, waste from wood processing and the food industry, and waste biomass from the industrial and municipal sectors.

Biomass Combustion and Efficiency

In renewable energy use, it is becoming increasingly necessary to address the consequences of global warming. In the past ten years, there has been renewed global interest in biomass as an energy source. In 2015, biomass combustion supplied approximately 14% of the total global final energy consumption. Modern bioenergy applications provided 14.4 EJ of heat in 2015, of which an estimated 8.4 EJ was for industrial uses and 6.3 EJ was consumed in the residential and commercial sectors (used principally for heating buildings and cooking). The modern biomass heat capacity in 2015 increased from an estimated 10 GWth to reach approximately 315 GWth (Renewable Energy Policy Network 2016).

The EU has set ambitious targets by raising the percent of EU energy consumption produced from renewable resources to 20% by 2020 and to 27% by 2030 (Proskurina *et al.* 2016). The largest problems occur in countries that have a relatively high-energy consumption pattern, such as France, Germany, and the United Kingdom. It is unlikely that they can comply with the expected renewable energy demand, unless they mobilize more woody biomass from their available domestic potential (France and Germany) or considerably increase their woody biomass imports (mostly wood pellets) from elsewhere (United Kingdom).

Within the several broad categories of combustion applications, the authors concentrated on community applications in this paper, including district heating. The majority of biomass used is wood biomass or lignocellulosic fibre (wood, chips, straws, corn cobs, pellets, briquettes, *etc*.). Each of the biomass combustion stages has a series of limitations that hinder the overall efficiency of heat generation and the maximum temperature reached. To ensure that combustion is as efficient as possible, it is essential to maximize the temperature, time, and turbulence. The role of turbulence is to ensure full and complete mixing of the fuel gases with oxygen during the process and ensure complete burning without diffusion limitations. Maximizing the time is required because the process of drying and paralyzing the solids are relatively slow processes, and maximizing the temperature increases the rate of all of the processes (McKendry 2002). A large variety of solids are moistened with liquid mixtures containing water and other substances. In the course of drying such solids, the composition of the moisture generally changes because different liquids evaporate at different rates. Therefore the different drying rates (drying times) needs to be taken into consideration. An ideal system would fully complete combustion before transferring the heat to a boiler, stove, or whatever application is desired.

RESULTS AND DISCUSSION

The Business Model and Heat Price Calculation

The heat production efficiency between Company A and Company B within one ownership group in Slovakia was analysed in this study. Company A produces and supplies heat and heated water for almost 90% for the residential sector *via* three biomass boilers with an installed capacity of 4000 kW each with the parameters given in Table 2 (100% biomass production), while Company B produces heat and heated water from gas (100% fossil fuel production).

Table 2. Heat System and Boiler Parameters– Company A

Parameter	Value
Maximum thermal power	3 × 4000 kW
Maximum operating temperature (*T*)	120 °C
Power efficiency	89%
Maximum Δ*T*	25 °C
Exhaust temperature	160 °C at MCR
O_2	7.5%
Maximum working pressure	4 bar
Fuel consumption at 100% power (for 1 boiler)	1076 kg/h
Thermal input of combustion at 100% load (for 1 boiler)	4488 kW
Amount of combustion gases at maximum power	7699 Nm^3/h = 8136,1 m^3/h 7699 Nm^3/h *(15.5+273)/ (0+273) = 8136,1 m^3/h
Amount of combustion air at maximum power (for 1 boiler)	6910 Nm^3/h

The state regulations were applied to heating companies in Slovakia, and the analysed production parameters and biomass fuel mix of Company A and Company B are presented in Tables 3, 4, and 5.

Table 3. Production Parameters

Item / Year	Company A	Company B
Delivered heat	26,100,000	77,100,000
°*D*	3040	3040
RP	5760 kW	17,930 kW
N_{EOP}	16,000 €	50,000 €
MFN_t	52.7 €/kW	41.5 €/kW
RAB and Rented assets	266,000 €	15,600,000 €
WACC	6.47%	6.47%
Reasonable profit (6.47% from RAB)	17,200 €	1,010,000 €

Table 4. Production Parameters and Biomass Fuel Mix- Assumptions

	Company A		Company B	
Produced heat	26,070,000	kWh	77,060,000	kWh
Power efficiency	88%		95%	
Fuel consumption	29,600,000	kWh	81,100,000	kWh
Fuel consumption	10,200	tons	8,000	ths·m^3

Table 5. Production Parameters and Biomass Fuel Mix- Company A

Fuel Type	Fuel Cost (€/MWh)	Percent	Biomass (kWh)	Biomass (GJ)	Cost (€)	Heat Value (GJ/t)	Biomass (t)	€/t
Chips[1]	16.20	73.0%	21,600,000	77,800	350,000	10,000	7,780	45
Corn cobs[2]	18.00	12.0%	3,550,000	12,800	63,900	12,000	1,070	60
Straws[3]	20.70	10.0%	2,960,000	10,700	61,300	11,300	944	65
Wood Briquettes[4]	28.00	5.0%	1,480,000	5,330	41,500	13,500	395	105
Total		100.0%	29,600,000	106,000	517,000	10,500	10,200	51

[1] Water content of 20-25% [2] Water content of 13-15%
[3] Water content of 3-8% [4] Water content of 10%

According to the regulation rules, each heating company needs approval given by the regulation body of fixed and variable costs structure on a yearly basis. The total costs could vary, but companies try to hold costs in a range of ± 5% because the approval costs structure is reflected in the final price for customers, which are very sensitive to price fluctuations. Therefore, for the management of each company, the kind of price structure strategy that will apply varies. The detailed calculation of the fixed and variable costs of the analysed companies are presented in Table 6.

Table 6. Calculation of the Fixed and Variable Costs

Cost		Company A		Company B	
		€/GJ	%	€/GJ	%
Variable Part	Fuel	20.30	84.7	24.600	65.8
	Purchased heat (variable part)			7.800	21.1
	Electricity	3.40	14.30	4.300	11.4
	Water	-	-	0.250	0.7
	Technology materials	0.24	0.01	0.375	1.0
	Total variable costs	23.90	100	37.300	100
Fixed Part	Rent	32.900	33.8		
	Purchased heat (fixed part)	-	-	30.600	15.5
	Insurance	0.208	0.2	1.950	1.0
	Inspections	0.945	1.0	4.750	2.4
	Amortization	1.420	1.5	83.100	41.9
	Service and maintenance	13.600	14.0	17.800	8.9
	Taxes	-	-	1.900	0.9
	Regulated part of fixed costs	33.080	34.0	38.500	19.4
	Reasonable profit	15.100	15.5	19.900	10.0
	Total fixed costs	97.300	100	199.000	100

As the company A and B belong to one investor, the company A buys biomass (as fuel cost) and produce heat. The produced heat is sold to company B, which sell heat to the final customers. Company B has therefore fuel cost (for gas) and cost for purchased heat from company A. This purchased heat is spitted between fixed and variable part, as according to the Decree, to the fixed part could company account the cost for purchased price up to approved regulation power limit, the rest above this limit is accounted to the variable part.

Assessment of the Economic Efficiency

The next part of the survey focused on the assessment of the economic efficiency of both analysed companies, while taking into account selective items from the balance sheets, profit and loss statements (2016 end year results), and the calculations of key performance indicators, which are presented in Table 7.

Table 7. Profit and Loss Statement and Balance Sheet– Selective Numbers

Item / FY 2015	Company A	Company B
Total Assets	1,548,000*	14,400,000
Equity	1,339,000	4,950,000
Liabilities	208,000	9,380,000
Total Revenue	1,125,000	6,848,000
Revenue of the fixed part	515,000	3,350,000
Revenue of the variable part	610,000	2,980,000
Costs	987,000	6,180,000**
Net profit	138,000	667,000
EBITDA	145,000	2,120,000
Adjusted EBITDA***	395,000	1,870,000
ROE	10.30%	13.50%
EBITDA share on REVENUES	35.10%	27.30%
RETURN on REVENUES	12.30%	9.74%

*Two boilers are rented within the group via Company B;
**Price for the purchased gas amounted to 26.30 €/MWh;
***EBIDTA was adjusted because of boiler depreciation in the amount of 250000 €, as they are rented and should be economically accounted for in the balance sheet of company A

The results of the financial analyses and calculated selective performance indicators confirmed two of the indicators, EBITDA share on REVENUES and RETURN on REVENUES, had higher values for Company A (pure renewable resources), while the ROE calculation differed and had a higher value for Company B (pure gas combustion). This was caused by the economics of scale, as Company A was relatively small compared with Company B, which was medium-sized, had a long run history, and optimized cost/income structure. This conclusion was confirmed by the work of Fan *et al.* (2017), who examined the interaction effect between the energy intensity and firm growth, and found that firm growth helps enhance the positive relationship between the energy intensity and financial performance. The results of this research showed that even small heating companies using renewable resources as a primary heat source with a short history could outperform traditional medium- and large-sized heating companies operating primarily with gas combustion.

Peer Group Comparison

As the two analysed companies could not serve as a benchmark, it was necessary to test the hypothesis of biomass combustion having a higher efficiency compared with gas combustion for more heating companies on the basis of a representative sample. Therefore, the next part of the study compared a peer group of economic results of ten heating companies, which were split into two groups. The first group consisted of heating companies with combined productions (gas and biomass), and is presented in Table 8a and 8b. The second group consisted of heating companies that used only gas as a primary source, and is presented in Table 9a and 9b.

Table 8a. Peer Comparison– Key Economic Indicators (Combined Production)

Item / Company	Energy Edge		Termming		Termonova	
Year	2015	2016	2015	2016	2015	2016
Installed capacity (renewable sources)	8.7 MW	8.7 MW	14 MW	14 MW	16 MW	16 MW
Produced heat (MWh)	69,600	69,800	169,000	169,000	44,500	44,300
Total Assets (T€)	21,090	27,800	21,300	22,500	14,300	13,300
Equity (T€)	1,053	1,990	4,560	4,710	4,360	4,600
Liabilities (T€)	20,030	25,800	16,400	17,500	9,520	8,300
Revenues (T€)	9,970	10,200	17,200	18,300	5,160	4,950
Costs (T€)	9,170	9,020	16,300	17,200	4,600	4,470
Net Profit (T€)	676	939	552	737	339	230
EBITDA (T€)	3,320	3,627	2,009	2,300	1,330	1,420
ROE	64.30%	47.20%	12.19%	15.70%	7.77%	5.02%
EBITDA / REVENUES	33.30%	35.60%	11.69%	12.60%	25.80%	28.80%
RETURN on RENENUES	6.79%	9.21%	3.20%	4.04%	6.55%	4.65%
Based on internal business information – approximately 80% forms wood chips and the rest is mix of other fuel types (valid for all companies).						

Table 8b. Peer Comparison– Key Economic Indicators (Combined Production)

Item / Company	Teplo GGE		Bytkomfort	
Year	2015	2016	2015	2016
Installed capacity (renewable sources)	4 MW	4 MW	6 MW	6 MW
Produced heat (MWh)	69,800	70,000	155,000	155,000
Total Assets (T€)	16,070	17,080	10,800	11,400
Equity (T€)	4,607	4,580	8,202	8,307
Liabilities (T€)	10,600	11,800	2,290	2,770
Revenues (T€)	16,400	17,100	10,070	10,200
Costs (T€)	15,500	16,500	9,160	8,960
Net Profit (T€)	490	376	688	771
EBITDA (T€)	1,740	1,750	1,530	1,620
ROE	10.60%	8.22%	8.38%	9.29%
EBITDA / REVENUES	10.60%	10.18%	15.21%	15.90%
RETURN on RENENUES	3.00%	2.19%	6.83%	7.58%

Table 9a. Peer Comparison– Key Economic Indicators (Primary Gas Production)

Item / Company	Bytterm		MeT Šaľa		PTH Prievidza	
Year	2015	2016	2015	2016	2015	2016
Installed capacity	146 MW	146 MW	13.7 MW	13.7 MW	127 MW	127 MW
Produced heat (MWh)	154,000	154,000	30,900	30,900	105,000	105,000
Total Assets (T€)	8,140	8,320	3,940	3,804	13,400	13,200
Equity (T€)	5,890	6,102	2,450	2,440	11,300	11,200
Liabilities (T€)	1,880	2,001	1,300	1,210	2,060	2,016
Revenues (T€)	16,800	17,300	2,500	2,475	9,660	9,660
Costs (T€)	16,400	17,100	2,520	2,460	9,370	9,610
Net Profit (T€)	645	658	-80	-15	226	272
EBITDA (T€)	1,250	1,250	475	544	1,590	1,280
ROE	10.90%	10.80%	-3.02%	-6.15%	2.0%	2.43%
EBITDA / REVENUES	7.46%	7.23%	18.90%	22.02%	16.50%	13.30%
RETURN on REVENUES	3.84%	3.81%	-2.95%	-0.61%	2.34%	2.82%

Table 9b. Peer Comparison– Key Economic Indicators (Primary Gas Production)

Item / Company	MBP Nové Mesto nad Váhom		Nitrianska Teplárenská Spoločnosť	
Year	2015	2016	2015	2016
Installed capacity	17 MW	17 MW	130 MW	130 MW
Produced heat (MWh)	38,500	36,000	136,000	140,000
Total Assets (T€)	11,100	12,270	16,600	17,400
Equity (T€)	2,650	2,670	12,700	12,600
Liabilities (T€)	8,410	9,480	3,890	4,740
Revenues (T€)	3,76%	3,660	13,200	12,500
Costs (T€)	3,760	3,640	11,900	11,300
Net Profit (T€)	-22	17	983	971
EBITDA (T€)	222	259	2,540	2,530
ROE	-0.85%	0.65%	7.77%	7.68%
EBITDA / REVENUES	5.91%	7.07%	19.30%	20.30%
RETURN on REVENUES	-0.60%	0.47%	7.47%	7.78%

The results from the conducted peer group comparison confirmed the hypothesis that heating companies with combined productions could reach higher values for the selected key performance indicators compared with heating companies that only use gas as a primary source. The individual values for each company were recalculated and the aggregated values were based on a weighted average. The first economic indicator focused on the achieved ROE. The companies in Group A reached ROE values of 18.86%, while those in Group B only achieved 3.22%. Therefore, Group A noticeably outperformed Group B in terms of the most important indicator, followed by the shareholders or investors. The second indicator measured the percent of EBITDA on REVENUES. The average value for Group A was 19.96%, while it was 13.82% for Group B. As the EBITDA was primarily comprised of depreciations and net profit, the results confirmed that Group A generated higher net profits compared with Group B. The last indicator calculated the percent of RETURN on REVENUES. Group A reached values of 5.40%, while Group B only achieved 2.44%. This definitely confirmed that heating companies with combined productions generate a higher profitability on average than companies that only use fossil fuels (primary gas). Theoretically, if the calculated average results for Group A were discounted by 15% (artificially) and that of Group B increased 15%, all three economic indicators of Group A would still outperform those of Group B. The results of the conducted research are summarized in Table 10.

Table 10. Summary Results- Key Economic Indicators

Indicator / Group	A Group	Range	Company A	B Group	Range	Company B
ROE	18.80%	<5.02% + 64.30%>	10.32%	3.22%	<-3.02% + 10.90%>	13.50%
EBITDA / REVENUES	19.90%	<10.20% + 35.60%>	12.90%	13.80%	<7.07% + 22.00%>	33.50%
RETURN on REVENUES	5.40%	< 2.19% + 9.20%>	12.30%	2.44%	<-2.95% + 7.80%>	9.70%

Based on the peer group comparison and outcomes from the research, Group A companies dispose presently up to 10 experience with biomass use for heating production purposes. The installed capacity (renewable energy) has been growing simultaneously with confirmed economic efficiency and acquired know how, but is still significantly lower compared to traditional heat production from gas. As green energy investments are supported by governments (*via* heat price calculation) and banks (*via* loans), we could forecast, that in a near future, biomass-fired boilers investments would follow and more and more transformations from pure gas heat towards biomass productions would occur. The motivation for the Group B companies is not just in a higher economic efficiency of combined production, but certainly in a diversification of fuel sources and potential risk from increased gas prices. As new green investments are recognised as an eligible costs and therefore could be incorporated into heat price calculation, investors would utilise this key factor into future investment plans.

Biomass has become an increasingly important energy source in many European countries over the past two decades. Generally, by expanding the use of biomass in the district heating systems, following issues needs to be taken into consideration:

- Legal acts and local policy instruments promoting the use of biomass,
- Trends in biomass prices from a long term perspective,
- Local biomass sources availability and potential given by forest industry,
- Technical and technology requirements, repairs and future investment needs,
- Future tendencies in using biomass in district heating systems.

In Slovakia, the introduction and expansion of biomass in the district heating system have been promoted by Renewable Energy Act and further by the Decree of the Office for Regulation of Network Industries, which has defined the precise heat price calculation and enable to achieve a reasonable profit. There has not been provided a special investment subsidies. However, some investors partially financed their transformation to biomass boilers technology via EU funds. The expansion of biomass in the district heating systems in Slovakia involved domestically produced wood fuels. The production of wood fuels is largely integrated in the forest industry and was developed based on existing structures and skills in this industry. Gradual technical development steps have taken place, first a shift from the initial use of biomass in existing boilers that were converted from fossil fuels to biomass to investments in new biomass-fired boilers. Second, there has been a shift from co-firing of biomass with fossil fuels to using biomass only. Due to the sufficient domestic sources and biomass supply, the biomass prices are stabilised and in the midterm trajectory do not represent a potential risk for heating companies and investors

The economic efficiency and key performance indicators strongly depend on the input prices of the energy carriers. According to the research study by Halaj *et al.* (2013), which compared the production costs of 1 GJ of heat, it can be stated that biomass, represented by wood fuel and wood chips, is the cheapest energy option for heat production. In the last decade, the cost of heat produced from natural gas amounted on average to two to three times the cost of deciduous wood. At present, there is a difference of 2.2 times that is in favour of wood fuel. Electricity is the most expensive way of obtaining heat from an energy carrier perspective and is currently almost six times more costly than wood fuel. The cost of heat produced from brown coal was 2.1 to 3.4 times lower than wood fuel. Several studies (Jungmeier and Sptitzer 2001; Moghtaderi *et al.* 2006; Zhang *et al.* 2010) confirmed that biomass waste from the agricultural and forestry industries are relatively low-cost and widely available compared with fossil fuels.

When switching from fossil fuels to biomass, it is necessary to take into account the investment costs and other operating costs associated with the transportation and storage of biomass. Because of transportation costs, the transition from fossil fuels to biomass is more feasible near suitable long-term potential sources of biomass (Zhu *et al.* 2011; Ba *et al.* 2016). With regards to rising fossil fuel prices and the processing capacities of the pulp and paper industry, the demand for fuel, wood fibre, and wood chips has increased in recent years, which is reflected by the rising prices of these commodities.

Historically, traditional heating companies and they heating networks have consisted of a few large, centralized generators that distribute heat one-way to end-users. In contrast, smart heating networks enable many decentralized generators to feed energy back to the grid. This provides thermal networks with greater flexibility and reliability. It also enables greater use of RE-H/C (resistence heating) and energy efficient technologies in district heating networks (Hegentoft and Kalagasidis 2015). However, the widespread deployment of smart district heating networks is prevented by numerous technical and market barriers, which policymakers and grid operators are just beginning to tackle, especially in Europe. Conventional district heating networks traditionally have supplied consumers using high- or medium-temperature heat in high-pressure systems. These systems typically are served only by biomass, combined heat and power, or fossil fuel boilers, and have hindered the widespread integration of low-temperature RE-H/C technologies, such as solar-heated water or advanced heat pumps (Rosa *et al.* 2012).

To address this technical barrier, district heating providers and energy planners are preparing to pilot low-temperature district heating grids. Because of their lower operating temperatures, such networks are much more efficient and can enable end-users to deliver low-temperature surplus heat from buildings back to the thermal grid. Low-temperature networks are expected to serve as the backbone of smart cities, which would increase the flexibility of communities to integrate RE-H/C and energy efficient technologies into buildings.

CONCLUSIONS

1. The use of biomass for energy purposes is one way of eliminating energy dependence on fossil resources, improving the quality of the environment and ensuring rural development. The relatively new sector within agriculture can replace some of the fossil fuel used, whose inventory is constantly shrinking.
2. The present study found that the share of renewable energy as a portion of the primary energy sources has constantly increased. The growing biological diversity positively affects the stability of forests in Slovakia and therefore represents an assumption for a long-term wood source. The biomass is a renewable energy source with the highest technical potential in Slovakia and presently the second most useable energy source.
3. The results of this research revealed that the combustion of biomass increased the efficiency of heating companies. It was found that all of the selected key performance indicators for the heating companies with combined production reached noticeably higher values compared with the heating companies that only use natural gas as a primary source, and resulted in higher values for investors. The results show that Group A companies reached 5.8 times higher ROE value, a 1.4 times higher EBITDA/ REVENUES ratio, and a 2.2 times higher RETURN on REVENUES ratio then Group B companies.
4. Wood pellets, wood chips and other agglomerated wood products are currently the most economical way of converting biomass into fuel and are a fast-growing source of energy in Europe. They can be used for power production or directly for combustion in residential and commercial heating.
5. The introduction of biomass in the district heating sector in Slovakia was supported by the national energy policy and facilitated by the existing resources, skills and infrastructures in the forest industry that merged with those of the district heating systems.

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