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HEAT PUMPS VERSUS BIOMASS BOILERS: A COMPARATIVE ANALYSIS OF HEATING COSTS FOR PUBLIC BUILDINGS

Key words: heating costs, renewable energy sources, heat pumps, biomass boiler

ABSTRACT. The aim of the study is a comparative analysis of heating costs of heat pumps and biomass-fired boilers. The study was carried out in the communes of Ruda-Huta (Chełm County) and Dębowa Kłoda (Parczewski County). The subject of the study were school complexes in which the heating system was changed from heating oil to ground heat pumps and a boiler house, working on fine coal, replaced by a biomass-fired boiler-house. The Levelised Cost of Heat (LCOH) method was used to assess heating costs in both facilities. In Poland, according to data for 2018, the basic carrier of renewable energy used in heating was biomass (90.5%), where the share of heat pumps was only 0.4%. The study shows that such proportions, at least in the public utility buildings heating sector, are not economically justified. Average heating costs, estimated using the LCOH method, turned out to be over 20% higher in the case of biomass than in the case of heat pumps. The attractiveness of this technology in heating is evidenced by the development of this market in Europe. Similar trends are also taking place in the world market. Due to the fact that electricity is most often used to generate this type of heat, the development of this sector will highly depend on the relation between its prices and prices of other energy carriers.

INTRODUCTION

Heating and cooling (the major part being heating) represented nearly half of the final energy consumption in the EU in 2018 [Bioenergy 2020] and no major changes in the quantitative sense are forecast in this respect [EC 2016]. However, due to obligations resulting from the ratification of the Paris Agreement by the European Union (4th October 2016), conventional fuels, which are also used for heating purposes, will be replaced with energy obtained from renewable sources. In the “Clean Planet for All” strategy, presented on 28th November 2018, the European Commission described a long-term vision for reaching zero net emissions in 2050. Among other things, it proposed the total abandonment of using coal and significant restrictions on the consumption of oil and gas [EC 2018]. Hence, the questions not only raised issues concerning technologies, but also the costs

of replacing traditionally-used conventional energy sources in the heating systems of EU countries. In 2018, these fuels covered more than 80% of the demand of this sector, with the main fuel being gas. In Poland, this index was even higher and amounted to around 86%, with the main energy source being coal [GUS 2020]. Directives 2009/28/EU of the European Parliament and the Council [OJ L 2009.140], 2009/125/EU [OJ L 2009.285] and 2010/31/EU [OJ L 2010. 153] stated that the key form of technology facilitating the achievement of EU targets for reliable, cost-effective and sustainable heat energy supplies will be heat pumps. Also, the project entitled “The Energy Policy of Poland until 2040”, presented on 8th November 2019 by the Ministry of Energy, stated “Thermal needs should primarily be covered using district heat. (...) If a connection to the heating network is not possible, one should strive to use individual sources with the lowest possible emission” [ME 2019]. Due to limited access to the transmission infrastructure in the area of heating and gas networks in the countryside, which in 2016, amounted to 1.7% (share in heat energy sales) and 23.3% [GUS 2018], respectively, in these areas, heat pumps [Gradziuk 2018, 2020] as well as biomass boilers [Brodziński, Pawlewicz 2015, Wyszomierski et al. 2016], can be one of the main sources supplying heating systems in both individual and collective constructions, as well as in the service and production sectors. In general, decisions about the choice of heating method are taken on the basis of costs, hence the aim of the study is a comparative analysis of heating costs using heat pumps and a biomass-fired boiler.

MATERIAL AND METHODS OF RESEARCH

The research was a continuation of many years of analyses regarding the efficiency of using renewable energy sources, mainly biomass and solar energy [Gradziuk 2006, 2012, 2014, P. Gradziuk, B. Gradziuk 2016]. Research was carried out in the communes of Ruda-Huta (Chełm County) and Dębowa Kłoda (Parczewski County). In the first case, the object of the research was a School Complex, where in 2012 the heating system was changed from heating oil to ground heat pumps. In Dębowa Kłoda research was also conducted in a School Complex, for heating with biomass (pellets), which has been in use since 2018. The Levelised Cost of Heat (LCOH) method was used to assess heating costs in both facilities [Hansen 2019, Forum Energii 2019]. Historically, this method is mainly used for electricity generation costs [Sandvall et al. 2017, Mikołajuk et al. 2016]. Using the formula below the average costs of generating 1 GJ of thermal energy for the entire period of operation of the tested heating systems were estimated.

$$LCOH = \frac{\sum_{t=1}^n \frac{I_t + F_t + M_t}{(1+r)^t}}{\sum_{t=1}^n \frac{E_t}{(1+r)^t}}$$

where:

$LCOH$ – Levelised Cost of Heat [PLN/GJ],

I_t – Investment expenditure in year t (amortization and cost of capital) [PLN],

F_t – fuel or energy costs in year t [PLN],

M_t – other costs in year t [PLN],

E_t – energy generation in year t [GJ],

r – average discount rate [%],

n – heating system lifetime.

Both school complexes received significant financial support for the implementation of the investments – RPO WL 2007-2013 and 2014-2020 and PROW among others. Due to this, in the conducted research, the efficiency of such a system was also simulated for actual costs incurred. Investment and operating costs were obtained from the accounting department of the School Complexes and Commune Offices.

CHARACTERISTICS OF THE OBJECTS

In both surveyed communes, measures have been taken for many years to improve energy efficiency, reduce greenhouse gas emissions and lower emissions. Such efforts mostly come down to thermal modernization or usage of renewable energy sources. In such proceedings, communes also saw a chance to reduce expenditure on the supply of energy carriers. For example, Ruda Huta commune completed 4 projects in this area for a total amount of PLN 9,298.9, where PLN 7,382.9 constituted financial aid for:

- the protection of environmental assets of the Ruda-Huta Commune by reducing emissions of harmful compounds to the atmosphere (stage I and II),
- the renovation of the boiler room with a heat pump system in the building of the School Complex in Ruda-Huta,
- the purchase and installation of heat pumps as an opportunity to take advantage of environmentally-friendly energy in the Ruda-Huta Commune.

In the same period, Dębowa Kłoda commune completed 3 such projects for a total amount of PLN 7,066.0, where PLN 5,151.8 constituted financial aid for:

- environmentally friendly energy and tourism in the Dębowa Kłoda Commune (stage I and II),
- thermomodernization of the commune office building in Dębowa Kłoda.

One of the main directions of using these funds was the replacement of heat sources in public utility buildings with ones powered by renewable energy sources. Conducted analyses show that different strategies of action were applied in surveyed local government units. While modernizing the heating systems in the Ruda Huta commune, heat pumps were only used in the School Complex in the beginning. In the first year after changing the heating system in the 3,600 m² school building, savings amounted to PLN 90,923.76. Such favorable results made the authorities of the commune take action to modernize the heating system in 6 other public utility buildings (in brackets the heat source before modernization):

- Municipal building – 712 m² (coal-fired boiler),
- Municipal Health Centre – 714.41 m² (oil-fired boiler),
- Communal Office of Ruda-Huta – 755.66 m² (oil-fired boiler),
- Centre of Culture and Recreation in Rudka – 608 m² (electrical heating),
- Culture Centre in Ruda-Kolonia – 214.18 m² (electrical heating),
- Culture Centre in Żalin – 269.24 m² (electrical heating).

In the Dębowa Kłoda commune, biomass (pellet) boilers were used instead of coal-fired boiler houses in the following modernized public buildings:

- Dębowa Kłoda School Complex – 2,262.15 m²,
- Kodeniec Primary School – 2,010.61 m²
- Municipal Office in Dębowa Kłoda – 457.21 m².

At the current stage of research, two facilities with the longest service life were chosen: School Complexes in Ruda Huta and Dębowa Kłoda. The first project included:

- the execution of geological work – 28 holes each with a depth of 100 m,
- the assembly of vertical collectors from PE pipes with a diameter of 40 mm,
- the installation and commissioning of 3 Danfoss DHP-R42 heat pumps with a capacity of 42.4 kW,
- adapting the existing central heating installation for operation with the heat pump system.

The Project was implemented under the measure “Basic services for the rural economy and population”, covered by the Rural Development Programme for 2007-2013, announced by ARiMR (ARMA – The Agency for the Restructuring and Modernization of Agriculture).

The scope of modernization, of the heating system in the Dębowa Kłoda School Complex included in the research:

- the disassembly of coal boilers,
- the delivery and installation of a biomass boiler (boiler for burning pellet) meeting the EN 303-5:2012 standard (or equivalent) with a power of 230 kW, where it is possible to burn cereal grains, fruit pips and nut shells,
- the assembly of a flue gas discharge system in the new biomass boiler,
- carrying out necessary adaptation work for the boiler room and fuel store.

RESEARCH RESULTS

The output data for LCOH calculations for both heating systems can be found in Table 1. Therefore, the investment expenditure took into account, apart from the heat pump system, the system with the existing fuel oil boiler (VITOPLEX 200 Type SX2), which serves the role of the peak and back-up heat source. It was installed in 2005 as part of thermo modernization works, hence the investment expenditure on such a heating system was estimated using the replacement method, taking into account, in addition to the boiler itself, safety and additional equipment, automation and the fuel oil tank together with the power supply installation.

Table 1. Technical and economic characteristics of heating systems of School Complexes in Dębowa Kłoda and Ruda Huta

| Specification | Dębowa Kłoda | Ruda Huta |
|---|--------------|------------|
| Total investment costs [PLN] | 417,831.00 | 616,500.02 |
| Subsidies [PLN] | 250,698.24 | 312,300.00 |
| Fuel or energy costs [PLN/year] | 43,808.90 | 67,325.25 |
| Other costs [PLN/year] | 8,761.78 | 2,107.74 |
| Discount rate [%] | 2.50 | 2.50 |
| The power of heat sources [kW] | 230.00 | 127.20 |
| Usable area of the building [m ²] | 2,262.15 | 3,621.23 |
| Installed power in relation to the heated area [kW/m ²] | 0.102 | 0.035 |
| Lifetime of the heating system [years] | 20 | 20 |
| Amortization [PLN] | 20,891.55 | 30,825.01 |
| Heat energy generation [GJ/year] | 542.26 | 1,221.18 |
| LCOH [PLN/GJ] | 145.21 | 112.94 |
| LCOH including subsidies [PLN/GJ] | 74.06 | 67.74 |

Source: own calculations

Performed calculations show that average costs of heat generation (LCOH) were by 22.2% lower in the case of heat pumps in relation to a biomass boiler house. Akram Fakhri Sandvall, Erik Ahlgren and Tomas Ekvall [2017] obtained similar results. On the other hand, different results were presented in the study of the Energy Forum think tank [Forum Energii 2019]. Analyses showed there conclude that among renewable energy sources the lowest heat generation costs come from biomass and then heating systems powered by heat pumps. The reason for the higher cost of biomass heat energy production in Dębowa Kłoda is the excessively high power of the biomass boiler in relation to the heated area. This indicator was almost three times higher than in the case of heat pump usage. During an interview designers stated that the power of the biomass boiler was selected so that it can act as a peak source as well.

Table 1 presents the results of the LCOH account in two options: with and without subsidies. Thanks to the financial support obtained, the costs of the generated heat energy, and thus heating, are around 50% lower when a biomass boiler plant is used, and around 40% in the case of heat pumps.

SUMMARY

One of the conditions for improving air quality in Poland, and, at the same time reducing greenhouse gas emissions, is promoting the use of renewable energy sources in heating. Buildings powered by individual heating sources are responsible for 90% of gas and dust emissions from the entire heating sector [Forum 2019].

The implementation of such facilities depends on the cost of heating in relation to other systems powered by both non-renewable and renewable sources. In Poland, according to data for 2018, the basic carrier of renewable energy used in heating was biomass (90.49%), where the share of heat pumps was only 0.4% [GUS 2019]. The study shows that such proportions, at least in the public utility buildings heating sector, are not economically justified. Average heating costs estimated using the LCOH method turned out to be over 20% higher in the case of biomass than in the case of heat pumps. The attractiveness of this technology in heating is evidenced by the development of this market in Europe. Similar trends are also taking place in the world market, as demonstrated by the actions taken, for example, by the authorities of New York [NYSERDA 2019] or the state of Pennsylvania [Blumsack et al. 2009] in the USA. Also, in Poland, their number in the years 2014-2018 increased almost threefold; however the amount of heat generated increased only by 23%. Such proportions result from the fact that in the years taken into consideration by this study, it was mainly air source heat pumps, which were installed (characterized by lower efficiency compared to ground source heat pumps). Due to the fact that electricity is most often used to generate this type of heat, the development of this sector will highly depend on the relation between its prices and prices of other energy carriers. In the analyzed period these relations were very favorable.

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POMPA CIEPŁA VERSUS KOCIOŁ NA BIOMASĘ:
ANALIZA PORÓWNAWCZA KOSZTÓW OGRZEWANIA
BUDYNKÓW UŻYTECZNOŚCI PUBLICZNEJ

Słowa kluczowe: koszty ogrzewania, źródła energii odnawialnej, pompy ciepła,
kocioł na biomasę

ABSTRAKT

Celem badań była analiza porównawcza kosztów ogrzewania przez zastosowanie pomp ciepła i kotła zasilanego biomasą. Badania przeprowadzono w gminach Ruda-Huta (powiat chełmski) i Dębowa Kłoda (powiat parczewski). Obiektem badań były zespoły szkół, w których dokonano zmiany systemu ogrzewania z zasilanego olejem opałowym na gruntowe pompy ciepła oraz kotłowni węglowej na opalaną biomasą. Do oceny kosztów ogrzewania w obu obiektach posłużono się metodą LCOH (Levelised Cost of Heat). W Polsce według danych dla 2018 roku, podstawowym nośnikiem energii odnawialnej stosowanym w ciepłownictwie była biomasa (90,5%), a udział pomp ciepła wyniósł jedynie 0,4%. Z przeprowadzonych badań wynika, że takie proporcje, przynajmniej w sektorze ogrzewnictwa budynków użyteczności publicznej, nie znajdują ekonomicznego uzasadnienia, bowiem uśrednione koszty ogrzewania, oszacowane z wykorzystaniem metody LCOH, okazały się o ponad 20% wyższe w przypadku zastosowania biomasy niż pomp ciepła. O atrakcyjności stosowania tej technologii w ogrzewnictwie świadczy rozwój tego segmentu rynku w Europie. Podobne tendencje występują również na rynku światowym. Z uwagi na to, że do wytwarzania tego rodzaju ciepła najczęściej wykorzystywana jest energia elektryczna, rozwój tego sektora uzależniony będzie od relacji jej cen do innych nośników energii.

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