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## **ECONOMIC EFFICIENCY OF APPLYING A HEAT PUMP SYSTEM IN HEATING BASED ON THE EXAMPLE OF THE RUDA-HUTA COMMUNE EXPERIENCE**

Key words: economic efficiency, renewable energy sources, heat pumps

**ABSTRACT.** The purpose of the conducted research was to assess the economic efficiency of the application of heat pumps in heating. The research was carried out in the Ruda-Huta Commune (Chełm County, Lublin Province). The research was conducted at the School Complex, where, in 2012, the heating system was changed from a system powered by fuel oil to a system of ground heat pumps. Due to the very low level of interest rates during the analysed years, the method of simple payback time, SPBT, was used to assess the economic effectiveness of this investment. The research shows that the application of a ground-source heat pump for heating the building of the School Complex in Ruda-Huta was economically efficient in comparison with the oil fuel system. The SPBT simple payback time was 2.14 years. Obtaining such a quick return on capital expenditure was a result of both significantly lower operating costs and obtained subsidy in the amount of approximately 50% of the total financial resources spent on the implementation of this project. Based on the obtained results, it can be concluded that the replacement of the oil heating system with heat pumps would be economically viable even without subsidies, but then the SPBT would extend to 5.48 years.

### **INTRODUCTION**

In the European Union, about 50% of consumed energy is connected with heating or cooling, and no major changes in the quantitative sense are forecast in this respect [EC 2016]. However, due to the obligations resulting from the ratification of the Paris Agreement by the European Union (4 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 28 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 coal use and significant restrictions on the consumption of oil and gas [EC 2018]. Hence, questions that arose not only concerned technology, but also costs of replacement of the traditionally-used conventional energy sources in the heating systems of EU countries. In 2016, these fuels covered more than 80% of the demand of this sector, the main fuel being gas. In Poland, this index was even

higher and amounted to around 86%, the main energy source being coal [GUS 2018]. Directives 2009/28/EU of the European Parliament and of the Council [Journal of Laws 2009.140], 2009/125/EU [Journal of Laws, 2009.285] and 2010/31/EU [Journal of Laws, 2010.153] stated that the key technology to achieve 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”, which was presented on 23 November 2018 by the Ministry of Energy, stated “If there is no possibility to connect to a heating network in a given area, heating needs should be satisfied by sources characterized by the lowest possible emissivity, in particular: gas installations, non-flammable renewable energy installations (including heat pumps), electric heating and the use of boilers for solid fuels of at least class V” [ME 2018]. Due to limited access to the transmission infrastructure in the area of heating and gas networks in the countryside, which, in 2016, amounted to respectively – 1.2% (share in heat energy sales) and 23.0% [GUS 2017], heat pumps could be one of the main sources supplying heating systems in both individual and collective construction, as well as in the service and production sectors in these areas. In recent years, the heat pump segment in Europe has become one of the most dynamically developing segments in the heating and installation market. The number of heat pumps, in operation, in the European Union, in 2017, amounted to 34.4 million and increased by over 170% in comparison to 2012. Similar trends are taking place in the global market, as demonstrated by undertakings of, for example, the authorities of New York [NYSERDA 2019] or the state of Pennsylvania [Blumsack et al. 2009], in the USA. In the same period in Poland, their number has more than quadrupled, however, the amount of produced energy increased only by about 64%. Despite such significant growth, in terms of the number of installations and the share of heat pumps in obtaining energy from renewable sources, Poland is still characterized by a relatively low level of utilization of this potential [P. Gradziuk, B. Gradziuk 2018]. In general, decisions about the choice of heating method are taken on the basis of costs, hence the purpose of the conducted research was to assess the economic efficiency of the application of heat pumps.

## 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]. The research was carried out in the Ruda-Huta Commune (Chełm County, Lublin Province). The research was conducted at the School Complex, where, in 2012, the heating system was changed from a system powered by fuel oil to a system of ground heat pumps. Due to the very low level of interest rates during the analysed years, the method of Simple Pay Back Time, SPBT, was used to assess the economic effectiveness of this investment. Using the following formula, it was possible to determine the time it would take for operational savings to offset the difference in investment expenditure.

$$SPBT = \frac{\Delta N}{\Delta Q}$$

where:

*SPBT* – payback time (year),  $\Delta N$  – investment expenditure (PLN),  $\Delta Q$  – annual savings (PLN/year).

SPBT was calculated both for costs without subsidies ( $SPBT_0$ ) and with subsidies (*SPBT*). Empirical data regarding the consumption of energy sources covered two periods, 2010-2012 (oil heating) and 2013-2018 (heat pumps). Investment and operating costs were obtained from the accounting department of the School Complex and the Commune Office.

### CHARACTERISTICS OF THE SITE

The Commune of Ruda-Huta (Chełm County, Lublin Province) belongs to a group of local governments characterized by the lowest personal income in Poland. According to the Local Government Service of the Polish Press Agency [Serwis Samorządowy PAP 2019], in terms of the G index – basic taxable revenue per capita, adopted to calculate the compensatory subsidy for 2017, this commune was classified as being in 2,395th position from among 2,478 basic local government units. Units located in poorer and less developed regions are forced to save [Jastrzębska 2016], so, in the implementation of public and social tasks, they usually follow the principle of minimizing expenditure, which guarantees the obtainment of the assumed level of results. This approach to managing financial resources was applied by the authorities of the Ruda-Huta Commune in, among others, supplying public utility buildings with thermal energy. In 2010-2018, expenditure for this purpose decreased by half, and its share in relation to budget revenues was reduced from 1.91% to 0.72% (Table 1), while at the same time improving the thermal comfort of users.

Such effects were obtained by changing the heating system - oil boiler rooms were replaced with heat pumps. The inspiration for the commune authorities to take action in this area was the call for proposals for granting financial aid under measure 321. “Basic services for the rural economy and population”, covered by the Rural Development Programme for 2007-2013, announced by ARiMR (ARMA – Agency for Restructuring and Modernization of Agriculture). Therefore, an application was filed under: “Renovation of a boiler room with a heat pump system in the building of the School Complex in Ruda-Huta”.

The prepared project received the approval of the Evaluation Committee, as a result of which aid was granted to the amount of PLN 388,750, but no more than 75% of the incurred eligible costs of the operation<sup>1</sup>. The scope of the project covered:

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

<sup>1</sup> Aid granting agreement no. 00190-6921-UM0300284/11 under the “Basic services for the rural economy and population”, covered by the Rural Development Programme for 2007-2013.

Table 1. Total income of the Ruda-Huta commune and expenditure on the purchase of fuels and electricity in 2010-2018

Years	Income	Expenditure on the purchase of fuels and electricity			
		total		heating	
	PLN	PLN	%	PLN	%
2010	15,168,679.74	474,218.60	3.13	289,596.58	1.91
2011	14,812,957.55	522,305.27	3.53	343,339.41	2.32
2012	14,059,424.99	536,171.76	3.81	338,683.61	2.41
2013	13,874,068.27	509,405.67	3.67	245,237.14	1.77
2014	15,339,620.61	449,275.07	2.93	191,374.10	1.25
2015	15,246,327.99	367,560.21	2.41	109,659.24	0.72
2016	17,764,846.80	430,562.03	2.42	140,162.10	0.79
2017	19,458,830.92	437,702.12	2.25	158,911.45	0.82
2018	20,264,215.53	420,286.01	2.07	145,862.28	0.72

Source: own calculations based on information obtained from the Ruda-Huta Municipal Office

Already, in the first year after the replacement of the heating system in the school building with an area of 3.6 thousand m<sup>2</sup>, the obtained savings amounted to PLN 90,123.76. Obtaining such a good result prompted commune authorities to take measures to modernize the heating system in 6 further public buildings:

- Municipal building – 712 m<sup>2</sup>, coal-fired boiler room,
- Municipal Health Centre – 714.41 m<sup>2</sup>, oil-fired boiler room,
- Communal Office of Ruda-Huta – 755.66 m<sup>2</sup>, oil-fired boiler room,
- Centre of Culture and Recreation in Rudka – 608 m<sup>2</sup>, electrical heating,
- Culture Centre in Ruda-Kolonia – 214.18 m<sup>2</sup>, electrical heating,
- Culture Centre in Żalin – 269.24 m<sup>2</sup>, electrical heating.

These tasks, known under the name of “Purchase and assembly of heat pumps as an opportunity to increase the use of environmentally-friendly energy in the Ruda-Huta Commune”, were implemented under the Regional Operational Programme of Lublin Province for 2007-2013, Priority Axis VI: The Environment and Clean Energy, Measure 6.2 Environmentally – friendly Energy<sup>2</sup>. In addition to the installation of heat pumps, a measuring and monitoring system was installed – providing for, among others, control via the Internet and measuring devices, which enable the collection of data on the operating conditions of each pump. The entire system has also been integrated with an Internet platform on which one can track online data on the actual performance of the operating installations and the achieved environmental effects. The value of the investment amounted to PLN 992 thousand, PLN 843 thousand of which was co-financed from the Regional Operational Programme of Lublin Province.

<sup>2</sup> Aid granting agreement no. 02/12-UDA-RPLU.06.02.00-06-112/12-00-0665 under the Regional Operational Programme of Lublin Province for 2007-2013, Priority Axis VI: The Environment and Clean Energy, Measure 6.2 Environmentally – friendly Energy.

## RESEARCH RESULTS

In order to assess economic effectiveness of an investment, a comparison is made of incurred or planned expenditure with expected revenues. In the case of the implemented project, its effects involve the savings obtained as a result of full or partial replacement of the heating of the school building with fuel oil by application of heat pumps. 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 a peak and back-up heat source. It was installed in 2005 as part of thermomodernization work, 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. According to prices from 2012, it amounted to PLN 104,328, thus it was five times lower than the costs incurred for the installation of heat pumps. Therefore, for the purpose of further calculations, it was assumed that the total investment costs of such a heating system amounted to PLN 616,500.02 (Table 2). Received public aid amounted to PLN 312,300 and was lower by PLN 76,450 than the value specified in the agreement, because a contractor was selected in the tender who offered a lower price than the amount specified in the application filed with ARiMR. The largest item in the structure of the investment costs was expenditure on the implementation of the lower source (geological work and installation of vertical collectors) and then the installation of heat pumps. As far as the remaining costs were concerned, the largest item was expenditure related to the spare (peak) heat source. In the case under study, it was a heating system powered by fuel oil.

As a result of the analysed investment, significant savings were achieved which, on average, after the installation of heat pumps, amounted to PLN 95,380.26 (in 2013-2018, in comparison with 2010-2012). The calculation included operating costs which covered the purchase of fuel and electricity, maintenance workers' pay, repair costs and technical inspections (Table 3).

Table 2. Structure of costs incurred for the installation of heat pumps at the Ruda-Huta School Complex

No.	Description	PLN	%
1.	Installation of the pump system	243,017.62	39.42
2.	Lower source construction	247,383.38	40.13
3.	Geological documentation	1,500.00	0.24
4.	Construction design	3,690.00	0.60
5.	Investor's supervision	8,586.02	1.39
6.	Surveying service	4,920.00	0.80
7.	As-built geological documentation	3,075.00	0.50
8.	Total installation costs for the heat pump system	512,172.02	83.08
9.	Installation costs of the oil fuel system	104,328.00	16.92
10.	Total investment costs	616,500.02	100.00

Source: own calculations based on the information obtained from the Ruda-Huta Municipal Office

Table 3. Operating costs of heating at the Ruda-Huta School Complex

Years	Heart pumps				Oil fuel system				Total PLN	
	electricity		total		oil fuel		others			total PLN
	PLN/kWh	kWh	PLN	PLN	PLN/l	l	PLN	PLN		
2010	-	-	-	-	2.76	56,400	155,664.00	1,200.00	156,864.00	156,864.00
2011	-	-	-	-	3.67	52,700	193,409.00	1,200.00	194,609.00	194,609.00
2012	-	-	-	-	3.96	41,400	163,944.00	1,200.00	165,144.00	165,144.00
2010-2012*	-	-	-	-	-	50,160	-	-	-	172,205.67
2013	0.74	98,676	73,020.24	1,200.00	-	-	-	-	-	74,220.24
2014	0.76	88,058	66,924.08	1,200.00	-	-	-	-	-	68,124.08
2015	0.69	83,830	57,842.70	1,200.00	-	-	-	-	-	59,042.70
2016	0.74	104,643	77,435.82	1,200.00	3.76	2,700	10,152.00	-	10,152.00	88,787.82
2017	0.73	80,846	59,017.58	11,306.00	3.06	11,800	36,108.00	-	36,108.00	106,431.58
2018	0.57	125,465	71,515.05	4,830.96	-	-	-	-	-	76,346.01
2013-2018*	-	96,919	-	-	-	-	-	-	-	78,825.41

\* yearly average

Source: own calculations based on the information obtained from the Ruda-Huta Municipal Office

Table 4. Indicators characterizing the efficiency of replacing oil heating with heat pumps

Specification	Oil fuel system	Heat pumps		$\Delta N_0$	$\Delta N$	$\Delta Q$
		without subsidies	with subsidies			
Investment costs [PLN]	104,328.00	616,500.02	304,200.02	512,172.02	199,872.02	-
Operating costs (yearly average) [PLN]	172,205.67	78,825.41	78,825.41	-	-	93,380.26
SPBT [year]	-	-	-	5.48	2.14	-

Source: own calculations

Table 4 presents the results of the SPBT account in two modes: with and without subsidies. In both, the time after which operating savings offset the difference in investment expenditure was very short and amounted to, respectively, 2.14 and 5.48 years. Similar results were obtained by Jaroslaw Wasilczuk and Marian Sobiech [2016], who concluded that, in comparison with gas heating, SPBT indexes may be much less favourable.

## SUMMARY

In recent years, the heat pump segment in Europe has become one of the most dynamically developing segments in the heating and installation market. Its development contributes not only to the fulfilment of commitments resulting from the climate and energy policy, but also contributes significantly to a reduction of low emissions and an improvement in quality of air. The use of such a system can significantly reduce the concentration of levels of particulate matter (PM 10) in the air, which is a serious threat to public health. Dust pollution PM10 is mainly caused by so-called low emissions (i.e. emissions from sources with a height not exceeding 40 m) usually arising from the combustion of low quality solid fuels in boilers and furnaces with a low emission standard. Dissemination of the use of such devices will depend on heating costs in relation to other systems supplied from both non-renewable and renewable sources. The research shows that the application of a ground-source heat pump for heating the building of the School Complex in Ruda-Huta was economically efficient in comparison with the oil fuel system. The SPBT simple payback time was 2.14 years. Obtaining such a quick return on capital expenditure was a result of both significantly lower operating costs and obtained subsidies in the amount of approximately 50% of the total financial resources spent on the implementation of the project. Based on the obtained results, it can be concluded that the replacement of the oil heating system with heat pumps is economically viable even without subsidies, but then the SPBT would extend to 5.48 years. Due to the fact that electricity is most commonly used to produce this type of heat, the development of this sector will depend on the relation between its prices and prices of other energy sources. In the analysed period, these relations were very favourable. The possibility of obtaining financial support under RDP as well as ROP played a very important role in the implementation of RES-related tasks in the studied commune.

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## EFEKTYWNOŚĆ EKONOMICZNA ZASTOSOWANIA POMP CIEPŁA W OGRZEWNICTWIE NA PRZYKŁADZIE DOŚWIADCZEŃ GMINY RUDA-HUTA

Słowa kluczowe: efektywność ekonomiczna, źródła energii odnawialnej, pompy ciepła

### ABSTRAKT

Celem przeprowadzonych badań była ocena ekonomicznej efektywności zastosowania pomp ciepła w ogrzewnictwie. Zostały przeprowadzone w Gminie Ruda-Huta (pow. chełmski, woj. lubelskie). Obiektem badań był Zespół Szkół, gdzie w 2012 r. dokonano zmiany systemu ogrzewania z zasilanego olejem opałowym na gruntowe pompy ciepła. Z uwagi na bardzo niski poziom stóp procentowych w badanych latach do oceny ekonomicznej efektywności tej inwestycji posłużono się metodą prostego okresu zwrotu nakładów SPBT. Z przeprowadzonych badań wynika, że zastosowanie gruntowej pompy ciepła do ogrzewania budynku Zespołu Szkół w Rudzie-Hucie w porównaniu do systemu zasilanego olejem opałowym było efektywne ekonomicznie. Wskaźnik prostego okresu zwrotu nakładów SPBT wyniósł 2,14 roku. Uzyskanie tak szybkiego zwrotu nakładów inwestycyjnych wynikało zarówno ze znacznie niższych kosztów eksploatacyjnych jak i uzyskanej dotacji w wysokości około 50% całkowitych środków finansowych wydanych na realizację tego projektu. Na podstawie uzyskanych wyników można wnosić, że zastąpienie ogrzewania olejowego pompami ciepła było ekonomicznie efektywne nawet bez dotacji, z tym że SPBT wydłużyłby się do 5,48 roku.

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