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ACQUISITION AND CONSUMPTION OF RENEWABLE ENERGY USED BY HEAT PUMPS IN 2010-2017 IN POLAND

Key words: energy acquisition, energy consumption, renewable energy, renewable energy sources, heat pumps

ABSTRACT. The article focuses on energy carriers previously performing a marginal role in the structure of obtaining energy from renewable sources, i.e. heat pumps. These energy carriers may, in the future, play an important role, because their importance in national states of affairs is increasing. The aim of the article is to assess the amount of energy obtained and consumed by heat pumps in 2010-2017, in Poland. The literature study method was used to implement the above-mentioned objective. The article uses secondary data from the Central Statistical Office. In the analyzed period, there was a systematic increase in the acquisition and consumption of energy obtained by heat pumps in Poland. The heat obtained using heat pumps in 2017 amounted to 2,688 TJ and was more than twice as high as in 2010. Heat pumps are a widely available technology and their use by households in Poland influences the implementation of energy policies of the country and the European Union, aimed at increasing the use of renewable energy sources. The case study method was used, where the heating costs of a single-family house, depending on the fuel used, were compared with constant assumptions.

INTRODUCTION

Renewable energy sources (RES) are sources not related to short or long-term inaccessibility regarding exploitation. Resources of renewable energy sources are replenished without limitation in time, as they come from recurring natural processes. In domestic conditions, energy from renewable sources includes energy from solar radiation, water, wind, geothermal resources and energy generated from solid biofuels, biogas and liquid biofuels, as well as ambient energy obtained by heat pumps.

The heat of the environment (natural environment) captured by heat pumps falls into the category of energy from renewable sources. Ambient heat is captured by heat pumps from atmospheric air, soil as well as ground and surface waters (rivers, ponds, lakes) [Vanden Borre 2011]. Taking into account the principles of naming energy carriers used in Directive 2009/28/EC of the European Parliament and the Council on promoting the use of energy from renewable sources [Journal of Laws, 140, 5.6.2009], they can be called: aerothermal energy (heat contained in ambient air), geothermal energy (heat accumulated

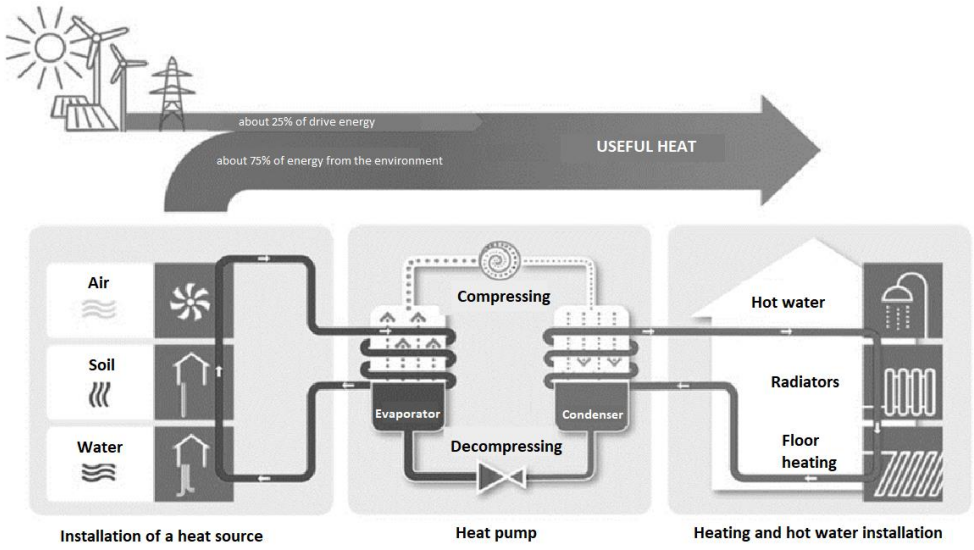

Figure 1. Construction and operation of a heat pump

Source: [PGreen Energy 2019]

in soil – top layer ground) and hydrothermal energy (heat contained in groundwater and surface water), respectively.

The heat pump is a practical heating and air-conditioning device, gaining popularity in countries of Western Europe and North America. The essence of its operation comprises of a heat exchanger, which absorbs the heat accumulated in nature. The exchanger is placed in the source of this energy, and the heat pump transforms the energy obtained. The incoming transformation is the transfer of the heat stream obtained from the environment in order to warm up the heat energy carrier located in the heating installation of the building to a high temperature. The assumption is to acquire heat energy at a low temperature and transfer it at a much higher temperature [Jasiukiewicz 2007]. The source of heat for a heat pump can be air, ground or water (Figure 1).

The first heating installations with heat pumps only appeared in Poland at the end of the 1980s. These installations, despite many imperfections, allowed to provide heat using cheap electricity. The technological blockade connected with heat pumps was broken down at the turn of the 80s and 90s of the last century, which contributed to the slow but consistent development of this technology in Poland [Grochal, Mania 2010]. Heat pumps, for several years, have gone from simple prototypes, initially only used for space heating, to high-tech devices, which make it not only possible to heat the house and provide hot water, but also increase the quality of life of residents by providing fresh air for optimum temperature. Heat pumps, due to their many advantages, can become a real alternative to coal boilers in the next few years. The advantages are, among others, lower energy bills, low operating costs and the possibility of using this device as an air conditioner in a building [PN-T "Euro Centrum" 2013].

MATERIAL AND METHODS OF RESEARCH

The purpose of the article was to assess the acquisition and consumption of environmental energy (natural environment) used by heat pumps, in 2010-2017, in Poland. The conducted analysis also contains information on the use of ambient energy obtained by heat pumps by households. The article uses secondary data from the Central Statistical Office and EuroObserv'ER reports. The article also presents an analysis of the profitability of selected types of fuels used for space heating and hot water for a single-family home.

RESEARCH RESULTS

The structure of obtaining energy from renewable sources for the Poland is based on (Table 1) the characteristics of the country's geographical conditions and possible resources for development. In the domestic acquisition (and consumption) of energy from renewable sources, in 2010-2017, in Poland, solid biofuels played a dominant role. Their share, however, decreases in the structure of energy obtained from RES.

Energy obtained from renewable sources, in Poland, in 2017 (Figure 2), mainly came from solid biofuels (67.9%), wind energy (14.0%) and

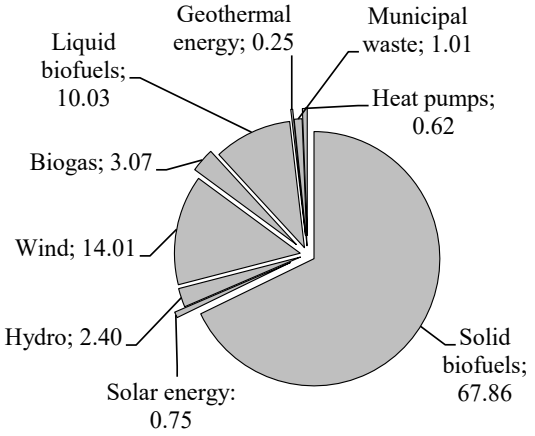

Figure 2. Structure of energy production from renewable sources by carriers in Poland in 2017 [%]

Source: own study based on [GUS 2018]

Table 1. The structure of obtaining energy from renewable sources for Poland

Source type	Share in the structure [%]							
	2010	2011	2012	2013	2014	2015	2016	2017
Solid biofuels	85.48	84.89	82.07	79.88	76.14	74.24	70.65	67.86
Solar energy	0.12	0.17	0.17	0.29	0.44	0.56	0.69	0.75
Hydro	3.66	2.68	2.06	2.45	2.31	1.77	2.03	2.40
Wind	2.09	3.68	4.79	6.03	8.13	10.51	11.92	14.01
Biogas	1.67	1.83	1.97	2.12	2.56	2.58	2.88	3.07
Liquid biofuels	6.38	5.76	7.96	8.18	9.18	9.10	10.16	10.03
Geothermal energy	0.20	0.17	0.19	0.22	0.25	0.24	0.24	0.25
Municipal waste	0.04	0.43	0.38	0.39	0.45	0.45	0.85	1.01
Heat pumps	0.36	0.39	0.41	0.44	0.54	0.55	0.58	0.62

Source: own study based on [GUS 2015, 2016, 2017a, 2018]

Table 2. Balance of energy obtained as ambient heat captured by heat pumps in 2010-2017

	The amount of energy [TJ]							
	2010	2011	2012	2013	2014	2015	2016	2017
Indigenous production	1,042	1,232	1,447	1,588	1,867	2,050	2,218	2,368
Inland consumption	1,042	1,232	1,447	1,588	1,867	2,050	2,218	2,368
Final energy consumption	1,042	1,232	1,447	1,588	1,867	2,050	2,218	2,368

Source: own study based on [GUS 2015, 2016, 2017a, 2018]

liquid biofuels (10.0%). Geothermal energy (0.25%), heat pumps (0.62%) and solar energy (0.75%) had a marginal share in the structure of obtaining energy from renewable sources, characterized by a year-to-year upward trend.

The balance of energy obtained as ambient heat captured by heat pumps in 2010-2017 is presented in Table 2. In the analyzed period, there was a systematic increase in the acquisition and consumption of ambient energy obtained by heat pumps in Poland. The energy obtained was consumed entirely within the country. Heat pumps use and will use all of the energy produced in Poland.

In 2010-2017, there was a systematic increase in the use of ambient energy captured by heat pumps (Figure 3). In 2017, the ambient heat obtained using heat pumps amounted to 2,368 TJ and was more than twice as high as in 2010.

In 2010-2017, the energy obtained by heat pumps was completely used in the trade and services sector and by households. In 2017, households consumed 71.6% of this energy, while the sector of trade and services 28.4% [GUS 2017a].

The consumption of ambient heat by households and the trade and services sector is presented in Figure 4. The consumption of ambient heat increased in the discussed period by 213% in households and by 271% in the trade and services sector.

According to the Central Statistical Office [GUS 2017b], heat pumps were used in 2015 for heating purposes only by 0.08% of households; to heat rooms by 0.07% and to heat water by 0.03%. The numerical increase in the heat pumps used is limited by the

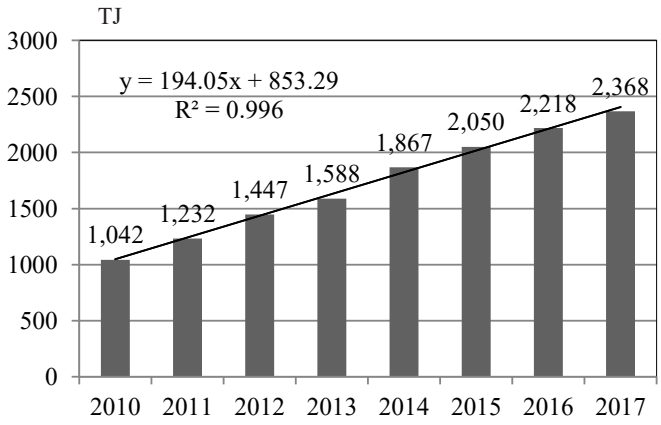

Figure 3. Energy consumption obtained by heat pumps in 2010-2017

Source: own study based on [GUS 2015, 2016, 2017a, 2018]

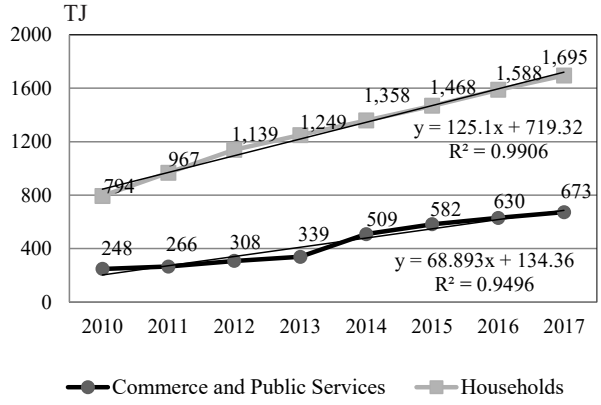

Figure 4. Consumption of ambient heat obtained by heat pumps in 2010-2017

Source: own study based on [GUS 2015, 2016, 2017a, 2018]

investment price as the expenditure on the heat pump is a cost of several dozen thousand zlotys. However, in times of rising energy prices, when heating utility water and buildings is a big expense in the monthly budget, an alternative solution for reducing costs, while minimizing environmental pollution, is the installation of a heat pump, which can increase the value of such a property. The assembly of this type of installation may also contribute to increasing the value of the property in which it is located. Heat pumps use free heat contained in water, air or soil, and produce hot water, but they can also heat the entire apartment or house. They can also be used to cool buildings during the summer [Chua et al. 2010].

Depending on the source from which the pump receives heat, we distinguish the following pumps [Wachowicz-Pyzik et al. 2015]:

– air/water (DHW), intended for heating domestic hot water,
– brine/water, use energy accumulated in the soil (otherwise ground),
– air /air – using the heat of the outdoor air, which goes to the air heating system, which ensures warm air in rooms,
– air/water, used for space heating,
– water/water,
– direct evaporation in the ground/water.

Heat pumps are considered one of the most efficient and ecological energy sources producing heat for the needs of central heating and DHW. Currently, a strong increase in interest concerns air- and ground-source pumps [Hakkaki-Fard et al. 2015].

The heat pump market has changed radically since the beginning of the 21st century, when sales results began to grow with the development of public awareness about environmental protection. According to Paweł Lachman [2014], observing the European heat pump market, it is visible that the dominant source for heat pumps is and will remain air in the near future. According to EurObserv'ER, as of the end of 2017, there were a total of over 34.4 million heat pumps operating in Europe, 95.6% of which constituted air-source heat pumps (Table 3). In Poland, in 2017, there were 109,000 heat pumps in total, including over 61.7 thousand air-source pumps and over 47.6 thousand ground-source pumps.

Table 3. Number of operating heat pumps in selected European Union countries in 2017

Country	Number of air-source heat pumps	Number of ground-source heat pumps	Number of all heat pumps
Italy	19,520,000	14,200	19,534,200
France	5,572,743	154,870	5,727,613
Spain	3,201,810	1,388	3,203,198
Sweden	1,136,341	525,678	1,662,019
Germany	616,569	358,181	974,750
Finland	683,621	110,981	794,602
Austria	92,808	103,120	195,928
Poland	61,731	47,655	109,386
The European Union	32,880,160	1,544,560	34,424,720

Source: own study based on [EurObserv'ER 2018]

Sales of ground-source heat pumps in Europe are definitely lower. Sweden, Germany and France have been at the forefront of the country for several years. In turn, the leaders in the use of air-source heat pumps are Italy, France, Spain, Sweden and Finland. Poland, in 2017, was in 12th place.

In the article, heating costs for a single-family home, depending on the fuel used, were calculated (Figure 5). It has been assumed that[1]: the heating area is 150 m^2, the house is inhabited by 4 people, the heat demand is 120 kWh/m^2/year, the consumption of domestic hot water (DHW) is 60 liters/person/day, cold water temperature = 10°C, required DHW temperature = 55°C, while the number of days of using DHW is 365.

In order to analyze the financial viability of individual heating systems commonly used in households, individual annual costs of heating and heating DHW for different heating systems were calculated. The total annual heat demand for a single-family house with the above-mentioned parameters is 22,585 kWh, of which 18,000 kWh is intended for heating the building, and 4,585 kWh for heating DHW. Annual heating costs with the use of an air-source heat pump amount to approx. PLN 5,600, whereas in the case of a ground-source heat pump, approx. PLN 3,400. For comparison, the heating costs for an energy-efficient house (heat demand = 70 kWh/m^2/year) are approx. 33% lower. Passive house (15 kWh/m^2/year) generates costs by about 70% lower, while older houses (insulated and non-insulated) are higher by approx. 27% and approx. 53%, respectively.

[1] According to Anna Wachowicz-Pyzik et al. [2015], in calculations, for a model installation, a single-family house was adopted, with a usable area of 150 m^2, inhabited by a family of four. The heat demand is 120 kWh/m^2/year – assuming the building is heat-insulated and built according to current standards. For comparison, the demand for heat in an energy-efficient home is from 30 to 70 kWh/m^2/year, and an older house without insulation from 170 to 200 kWh/m^2/year. In addition, daily consumption of hot water was assumed to be 60 liters/person/day, where: 40 liters/person/day – means low needs; 60 liters/person/day – standard needs; 80 liters/person/day – increased needs; 100 liters/person/day – very high needs.

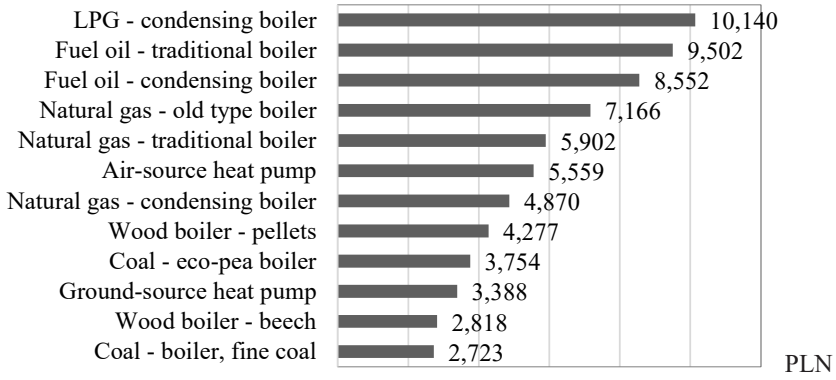

Figure 5. Costs of heating a single-family home in PLN gross/year depending on the fuel used

Source: own study based on [A-pic 2019]

A preferred solution for owners of detached houses (existing buildings) or persons permitted to start building a house may be the government programme "Clean Air", operating from September 2018. The most important goal of the programme is to reduce emissions of harmful substances into the atmosphere that arise from heating low-quality, single-family houses in outdated domestic stoves. By taking part in the programme, it is possible to obtain subsidies for the purchase of a heat pump, among others. The growing awareness of homeowners who increasingly focus on innovative, maintenance-free and cost-saving home heat systems contributes to the fact that interest in receiving subsidies under this project is increasing [MŚ 2018].

The "Clean Air" programme is implemented by the Ministry of Environment in cooperation with the Bank for Environmental Protection, while applications are accepted by the Voivodship Fund for Environmental Protection and Water Management. The programme is addressed, in particular, to people with a low or medium income, while co-financing under the programme varies from 30 to 90% of eligible investment costs. The Bank for Environmental Protection may grant low-interest loans to those contributing own funds within the programme. The maximum eligible cost in the programme is 53,000 PLN, the minimum – 7,000 PLN. The planned completion time of the programme is 2029. The call for proposals is to be conducted on a continuous basis, and the implementation of this project is estimated at PLN 103 billion [NFOSiGW 2018].

In the case of existing buildings, the programme provides co-financing for: the replacement of old heat sources for heat pumps or other heat sources that meet the programme's requirements, assembly or modernization of the internal central heating and hot water installation, purchase and assembly of mechanical ventilation with heat recovery, and the insulation of building walls. In the case of newly built houses, the subsidy can be obtained for the purchase and installation of both an air-source heat pump and a heat pump extracting heat from the ground or water [Zielona Eskadra 2018].

CONCLUSIONS

Heat pumps are a widely available, mature, highly effective technology that fits perfectly into both the EU energy policy and the current energy policy of Poland. In the years 2010-2017, the increase in energy obtained by heat pumps more than doubled. In 2010, it was 1,042 TJ while in 2017 it was 2,368 TJ. At present, there is a systematic increase in the use of ambient energy captured by heat pumps in Poland. As a result, their share in the structure of obtaining energy from renewable sources is increasing. The share of energy obtained by heat pumps in obtaining total energy from renewable sources increased from 0.36% in 2010 to 0.62% in 2017. Heat pumps use free heat contained in water, air or soil, and then produce hot utility water, but can also heat a whole flat or house. The most popular type of heat pump in the EU, in 2017, was the air-source heat pump, which accounted for nearly 96% of all installations. Heating costs with the use of an air-source heat pump are half as high as in the case of the most expensive installation, the LPG condensing boiler, but also twice as high as in the case of the cheapest type, the fine coal boiler. However, in the case of increasingly used ecological heating systems (such as natural gas boilers), ground and air-source heat pumps are the cheapest solution. In addition, the difference in heating costs in the case of the cheapest installation and the ground-source heat pump (in the case studied) is about PLN 600 which, considering the high environmental harmfulness of fine coal boilers and low for modern solutions using heat pumps, is an acceptable amount for a growing group of people.

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POZYSKANIE I ZUŻYCIE ENERGII ODNAWIALNEJ WYKORZYSTYWANEJ PRZEZ POMPY CIEPŁA W LATACH 2010-2017 W POLSCE

Słowa kluczowe: pozyskiwanie energii, zużycie energii, energia odnawialna, odnawialne źródła energii, pompy ciepła

ABSTRAKT

W artykule zwrócono uwagę na nośniki energii spełniające dotychczas marginalną rolę w strukturze pozyskiwania energii ze źródeł odnawialnych, tj. pompy ciepła. Nośniki te mogą w przyszłości odegrać bardzo istotną rolę, ponieważ wzrasta ich znaczenie w warunkach krajowych. Celem artykułu była ocena wielkości pozyskiwania i zużycia energii otoczenia (środowiska naturalnego) wykorzystywanej przez pompy ciepła w latach 2010-2017 w Polsce. Do realizacji wyżej wymienionego celu zastosowano metodę studium literatury. Wykorzystano m.in. dane wtórne pochodzące z GUS za lata 2015-2018. W badanym okresie w Polsce wystąpił systematyczny wzrost pozyskiwania i wykorzystania energii otoczenia pozyskiwanej przez pompy ciepła. Ciepło otoczenia pozyskane z wykorzystaniem pomp ciepła wyniosło w 2017 roku 2368 TJ i było ponaddwukrotnie wyższe niż w 2010 roku. Pompy ciepła są powszechnie dostępną technologią, a ich wykorzystanie przez gospodarstwa domowe w Polsce wpływa na realizację polityk energetycznych kraju, a także wszystkich państw członkowskich Unii Europejskiej, których celem jest zwiększenie wykorzystania odnawialnych źródeł energii. Zastosowano metodę studium przypadku, gdzie przy stałych założeniach porównano koszty ogrzewania domu jednorodzinnego w zależności od wykorzystywanego paliwa.

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