

Ecological Analysis of Heat Pumps in Poland in Terms of Carbon Dioxide Emissions [†]

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Abstract: The purpose of this work is a comparison of indirect carbon dioxide emissions between the different heat pump types that operate in Polish climate conditions. This analysis embraces an air–water heat pump (ASHP), ground–water heat pump (GSHP), water–water heat pump (WSHP), and a WSHP with a separating heat exchanger (SHE) in the selected towns, one in each climatic zone in the country. The study starts from a computation of heat demand and electrical energy consumption in every hour of the heating season using temperature values taken from a typical meteorological year (TMY). Then, seasonal coefficient of performance (SCOP) values are determined, which enables an assessment of which kind of heat pump meets the European Union requirements in every location. Eventually, indirect CO₂ emissions that are caused by electrical energy production are estimated for every heat pump in each location.

Keywords: heat pump; carbon dioxide emissions; ASHP; GSHP; WSHP

1. Introduction

Increasingly disturbing temperature rise gives a base for threatening forecasts, which forces countries and international institutions to reduce temperature increase. One of the remedial measures taken by the European Union (EU) is aspiration to energy production in climate neutrality way [1]. For this reason, the EU promotes the replacement of high-emission heat generators in the central heating systems by heat pumps. Heat pumps does not directly emit any pollutions to the atmosphere, but indirect emissions are done during generation of power necessary for their operation [2]. Due to their growing popularity and diversity in thermal reservoirs or operating parameters, the European Commission introduced regulations that specify the minimum value of the seasonal coefficient of performance (SCOP) [3]. The purpose of this work is a comparison between indirect carbon dioxide emissions values for different types of heat pumps in Polish climate conditions.

2. Material and Methods

There are analyzed heat pumps in respect of 4 types of thermal reservoirs that are freely available on the market: an air to water heat pump (ASHP), ground to water heat pump (GSHP), water to water heat pump (WSHP) and a water to water pump. The operation of WSHP can be supported by the separating heat exchanger (WSHP + separating heat exchanger (SHE)). The devices will be the only heat generator in a detached house with a designed heat load 12 kW in five selected locations, one in every Polish climatic zone: Szczecin, Poznań, Łódź, Białystok, Zakopane. Outside temperature values

are taken from a typical meteorological year (TMY) in each town, which seems to be the best approximation of the climatic conditions.

Since heating degree days (HDDs) and the average monthly outside temperature are used in the analysis as the climatic factors, it must be assumed that outside temperature is constant all month. Due to the fact that the COP depends on outdoor temperature and the dependence is not linear, such averageness may seem too far. Therefore, it was decided to consider the second temperature variant assuming that the average minimum temperature value equals the difference between the average monthly temperature value and half of the monthly amplitude value. These variants will be marked with the symbols 'I' and 'II', respectively.

At the initial stage of the analysis, the temperature values of the lower sources were determined. Temperature values for ASHP are equal to outer temperature. In the variant of GSHP, it is necessary to determine a soil temperature profile, which is done using the Baggs formula modified by the team led by Oleśkiewicz-Popiel [4] for the Northern Hemisphere. In the case of the WSHP pump, the groundwater temperature value is needed as the groundwater basin is a lower heat source. These values are obtained from the relation described by Kowalski [5]. If WSHP had to be separated from the groundwater with SHE, a brine temperature decrease of 2 °C is assumed.

Further calculations of COP and SCOP values are based on the algorithms of applicable European standards [6,7].

Eventually, the indirect carbon dioxide emissions are determined for each system at every location. To do it, an algorithm, which is derived by Gajewski et al. [8], is used.

3. Results

The results of the analysis are presented in the full text of the publication. They compare the SCOP values determined with the obligatory EU regulations as well as the carbon dioxide emission values between the analyzed technological models.

Author Contributions: S.S. and A.G. created a calculation algorithm. S.S. did the computations of SCOP, A.G. did the computations of emissions, and S.S. and A.G. analyzed the data and wrote the paper. All authors have read and agreed to the published version of the manuscript.

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