Energy Self-Sufficient Public Utility Building—Concept †

Karolina Dec * and Elżbieta Broniewicz

Department of Civil Engineering and Environmental Sciences, Bialystok University of Technology, 15-351 Bialystok, Wiejska 45A, Poland; e.broniewicz@pb.edu.pl

* Correspondence: k.dec@doktoranci.pb.edu.pl; Tel.: +48-515-834-214
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Abstract: In this study, the idea of an energy self-sufficient public utility building was presented, as well as its energy balance components and the possibility of powering it with renewable sources. The annual energy consumption profile of the building was analyzed. Current data concerning the production of electricity from Renewable Energy Systems (RES) were presented. The applicable provisions of the Directive of the European Parliament and the EU Council on energy efficiency were discussed.

Keywords: self-sufficient; renewable energy sources; photovoltaic; ground source heat pump

1. Introduction

This work is aimed at developing a concept of an energy self-sufficient public utility building. Currently, in the EU, the construction sector, including public utility buildings, is responsible for almost 40% of the total final energy consumption [1]. The latest version of the Energy Performance of Buildings Directive 2018/844 requires that from 2021, all newly constructed buildings should be nearly zero-energy buildings, and from 2019 onwards, the requirement applies to new public buildings [2]. The seasonal and random nature of renewable energy sources is the biggest problem regarding their practical usage. Energy storage may enable us to adjust the efficiency of an energy source to an equally variable energy demand. In the case of electricity, it can be stored within the power grid. Thermal energy can be stored using the thermal capacity of liquids and solids, the heat of phase transformations and using chemical and photochemical processes.

2. Materials and Methods

The work was carried out based on data on the electricity and heat consumption of the existing primary school building. The electricity yield forecast was carried out using the interactive tool PVGIS. After the analysis of the possibility of using renewable energy sources to power the building (using Snakey’s chart [3,4]), a concept was formulated, according to which photovoltaic panels will power the building, and the source for low-temperature heating will be a ground heat pump. A system of solar collectors will provide hot water. The possibility of draining excess heat from the collectors in summer to the ground was presented, using borehole thermal energy storage (BTES) technology, which will also allow for its storage in the ground and increase the efficiency of heat pump performance. Initial estimates were made. The economic and ecological effects of the investment were determined. Possible sources of financing were proposed. The binding laws and standards were used as the basis for the study.
3. Results

The conceptual design of photovoltaic, photothermal and heat pump installations up to 50 kW, and installation ensuring the energy self-sufficiency of the building, was realized. In addition, the possibility of using a BTES (borehole thermal energy storage) system was discussed.

3.1. Energy Efficiency

Following the estimation of the heat demand for heating the building per unit area, the building was classified as energy-efficient. In the case of electricity, the area demand is about 13 kWh/(m²·year). The daily heat demand for hot water preparation, which has been calculated for 1400 building users, is about 4 GJ.

3.2. Photovoltaic

Installation of up to 50 kW would not cover the energy demand of the building. As a result, a system with an output of about 180 kW is being considered, which ensures the energy self-sufficiency of the building, including the energy consumed by a ground source heat pump with a Coefficient Of Performance (COP) of 4.7.

3.3. Ground Source Heat Pump

The one-compressor ground source heat pump was selected, with a rated thermal input of 111 kW. The heat pump will operate in the alternative, mono-energy mode. This mode is used when the pump covers approximately 90% of the annual heat requirement and is supported by an additional electrical heat source (electric instantaneous water heater) [5].

3.4. Solar Collectors

The estimated demand for hot water requires the installation of 70 large area flat-plate collectors with a total absorption area of about 660 m². The collectors will be laid on a sloping roof slope on the south and south-east side. The possibility of using installation to store excess heat energy from solar collectors in the BTES [6] system was suggested.

4. Conclusions

This article proposes a system supplying electricity, low-temperature heating and domestic hot water. The installation consists of photovoltaic panels, solar collectors and a ground source heat pump. Moreover, attention was paid to the possibility of using, apart from the conventional ground source heat pump system, the BTES system, which, thanks to the appropriate configuration of the ground source heat exchanger system and the seasonal reversal of the medium flow direction, would allow the use of the excess heat energy coming from the solar collector installation [7]. This solution, by raising the ground temperature, would make it possible to increase the efficiency of the ground heat pump’s energy extraction.

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