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Data Analysis of the Energy Performance of Large Scale Solar Collectors for District Heating

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Abstract

District Heating systems are an interesting opportunity for the increase of renewable energy share in the heating and cooling sector. The possibility of a centralized heat production allows the integration of multiple sources, including RES such as biomass, heat pumps and solar energy. This paper provides an operation analysis of the energy performance of large scale solar collectors supplying heat to DH systems in Denmark. Thanks to the availability of hourly data it has been possible to track the evolution of the collectors' performance throughout the year, and compare it with the available radiation. The results show the good reliability of such systems, which are generally able to convert 40% to 60% of the available radiation, with annual production yields higher than 400 kWh/m^{2}y. The conversion efficiency shows some seasonal variations, being the winter months the less favorable, probably because of a lower direct radiation. The DH systems considered in the study show a similar performance but with some differences: other parameters such as slope, azimuth and operating temperatures could be the causes of these variations.

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Keywords: Solar Energy, District Heating, Renewables, Operation Analysis

1. Introduction

District Heating (DH) systems are an interesting solution for the increase of the share of Renewable Energy Sources (RES) in the heating and cooling sector, which is among the energy targets of the European Union [1,2]. DH systems can play a major role through sustainable and efficient thermal energy production, within the Smart Thermal Grids concept framework [3–5]. The centralized production of heat has multiple advantages, including a better generation management and integration of multiple sources, the possibility of Combined Heat and Power (CHP) generation and environmental benefits on pollutant emissions [5]. Moreover, DH systems can be used to increase the heat production from RES, including biomass, heat pumps and solar energy. A number of DH systems are using large scale solar collectors, often coupled with seasonal storage. Solar generation for DH systems is a mature technology in some countries, while it is gaining interest in other countries as an actual solution to lower the share of fossil fuels [6–8]. The average annual heat productivity from solar collectors is usually in the range 350 - 450 kWh/m^2 [9], depending

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however un multiple factors (available radiation, outdoor temperature, collectors features, operating temperatures, etc.).

There are usually some aspects to be considered for the development of solar systems coupled to DH networks, among which:

- supply and return temperatures of the DH network;
- daily and seasonal heat load profiles;
- interaction with existing generators;
- land availability and cost.

These aspects can be quite different from country to country and system to system, as they are related with a number of external factors. The first country where solar energy has been strongly used for DH supply is Denmark, thanks to some favorable factors and a strong political and cultural vision.

In this paper an operational analysis of large scale solar collectors is presented, with the aim of describing the actual performance of the systems that are currently in operation. The possibility of considering multiple sites and design conditions (e.g. type of collectors, makers, slope, etc.) allow for generalized results.

2. Methodology

2.1. Available Data

The data used for this analysis have been downloaded from Solvarme website [10], where a huge amount of hourly data are available for a number of solar DH networks. This website includes some of the Solar DH systems of Denmark. The analysis has been performed with R software [11].

Table 1 show the number of systems for which operation data are available over the years. The systems are not all the existing systems in Denmark, as many others are still not connected to this monitoring system. Moreover, some systems are in operation since before 2007, but there are no data available before 2007.

The number of monitored systems has considerably increased in last years, and so did the total collectors' surface. Considering all operating systems in Denmark, as of October 2016 the total installed surface has reached 1 million m^2 in 85 solar DH systems in the country [12]. And they are always getting larger: in Silkeborg (Central Denmark) the largest plant of the world has been built in the end of 2016:it has 156,000 m^2 of collectors' surface and a nominal peak power of 110 MW.

Table 1. Features of the systems per year

Year	DH Systems	Estimated Surface [m²]
2007	2	17,000
2008	3	22,000
2009	5	75,000
2010	10	115,000
2011	17	180,000
2012	25	256,000
2013	32	329,000
2014	40	469,000
2015	49	563,000
2016	56	723,000

The dataset, for which the narrowest available time step is one hour, contains: (1) Heat Generation, (2) Specific Heat Generation and (3) Available Radiation. The estimated total surface of Table 1 has been calculated using the ratio between heat and specific heat. As a result, this value is probably not precise, due to possible errors in the operation data.