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Research Paper

Performance indicators of District Heating Systems in Italy – Insights from a data analysis

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HIGHLIGHTS

- Performance indicators for several district heating systems are calculated.
- All calculations are based on real operation data, considering multiple parameters.
- The primary energy factor of the heat from district heating shows some variability.
- The main drivers are the energy source, the cogeneration use and the network losses.

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ABSTRACT

District Heating Systems (DHS) are a solution for the supply of heating and cooling in urban areas. Thanks to the possibility of exploiting multiple energy sources, a well-designed and well-operated DHS can allow primary energy savings, CO_2 emissions reduction and integration of renewable energy sources for the heat generation. However, each DHS has its own peculiarities and its conversion and distribution efficiency is affected by several factors, including design parameters as well as operational choices and potential unexpected behaviours. Performance indicators calculated on a statistically relevant set of DHS can provide useful insights on their range of variability. This paper analyzes the performance of several DHS, by calculating the primary energy factor and the CO_2 emission factor of the heat supplied to the users, using the current methodology defined by the European Standards. The results show that the efficiency of DHS is mainly affected by the energy source and the conversion technologies, but also the network losses have a crucial impact on the overall performance. The majority of the DHS included in this analysis supply heat to the users with a primary energy factor in the range 0.9–1.8 and a CO_2 emission factor between 0 and 0.30 kg/kWh. The operation of Combined Heat and Power generation units connected to DHS needs to be analyzed with reference to the characteristics of the electricity available on the National Power Grid.

1. Introduction

Heating and cooling of buildings accounts for a significant share of the final energy consumption in Europe. Almost three quarters of the European population lived in urban areas in 2015, and this trend is expected to further increase. In this context, District Heating Systems (DHS) can provide an effective solution for the supply of heat to final users in an efficient and sustainable way [1]. The current development of DHS varies from one country to another: while some countries such as Denmark, Sweden and Latvia have very high shares of heat supplied by DHS, in other cases the potential of DHS penetration is still considerable (e.g. Spain, Italy, Norway). Moreover, DHS include a high variety of energy sources and conversion technologies, which are generally related to local available resources, energy costs and historical reasons. The use of DHS instead of traditional heating provides additional benefits for the users, such as lower maintenance costs, higher reliability of heat supply and lower environmental pollution.

In the framework of the European goals for climate and energy policies [2], DHS can provide a viable solution for increasing the energy savings and the renewable share of the energy mix, and for decreasing the greenhouse gases emissions. DHS are often showing high conversion efficiencies by exploiting Combined Heat and Power (CHP) [3,4] production and Waste Heat Recovery (WHR) [5]. These technologies optimize the overall efficiency of the energy conversion system by exploiting a surplus heat that would have otherwise been dissipated. The possibility of using Renewable Energy Sources (RES) in DHS is a key factor: a number of systems are currently using wood biomass [6,7], geothermal energy [8], heat pumps [9] and solar energy [10]. The

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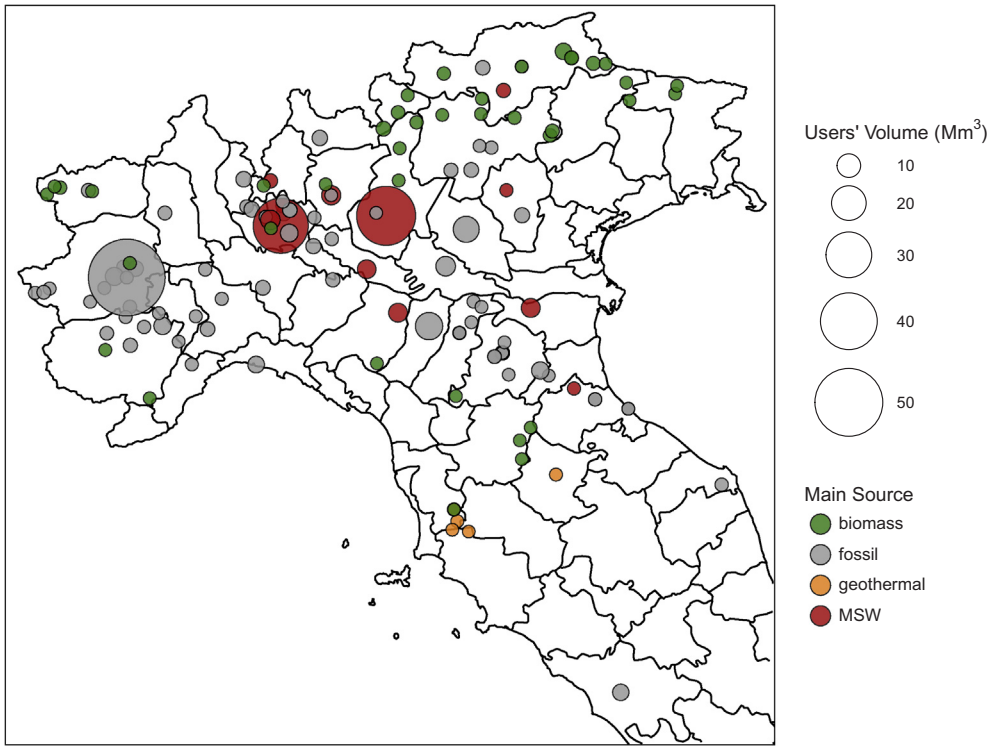

Fig. 1. Map of Italian DHS.

potential increase for RES is still considerable, and each country has set specific National targets.

DHS are currently facing the challenge of becoming thermal smart grids [1], with similar opportunities and risks of the better-known electric smart grids. The optimization of the heat supply needs to face a number of aspects, including energy generation and demand matching, heat storage [11], operational optimization [12,13], demand side management [14], distributed generation [15], and a careful design of the network [16–18]. The possibility of exploiting a significant amount of operation data from monitoring systems gives multiple advantages in optimization [19] and load forecasting [20], increasing the accuracy of DHS simulation models [21] or dedicated energy analyses [22]. The difference among actual and design data should not be neglected when evaluating the performance of any DHS [23].

However, there is currently no research work that calculates some basic performance indicators such as the Primary Energy Factor (PEF) or the CO_2 emission factor on a large number of DHS from real data. The majority of European Countries is relying on reference values when considering the PEF of their systems [24], and the calculation of real PEFs from operation data could provide an insightful indication for energy planning and policy making.

Some papers provide statistical information about DHS, both from an International perspective [25], and with a focus on specific countries such as Denmark [26], Sweden [27], or Finland [28]. These works provide interesting reference information on the District Heating Sector in those countries, with particular reference to the main sources and the DHS share with respect to other technologies for heating and cooling. In some cases reference data on the specific CO_2 emissions per unit of delivered heat is provided.

There are a number of studies that use primary energy or CO_2 emissions as parameters for specific studies applied to DHS [29] or to buildings supplied by DHS [30], but they are generally applied to a single system or to few case studies, without the aim of providing reference indicators for other uses.

This work presents the results of the calculation of different performance indicators on the real annual operation data of the DHS in Italy. The knowledge of the current performance of existing DHS is essential both for the planning of future systems and for the further optimization of existing ones. In particular, the performance indicators considered in this study are focused on primary energy consumption and CO_2 emissions. An additional analysis has been performed on CHP units, as their operation has considerable impacts on the performance of DHS, and they represent a significant share of the heat production in Italian DHS. The methodology applied in this study can be extended to other countries.

2. Methodology

2.1. Aim of the analysis

The aim of this research work is the calculation of real performance parameters of existing DHS, based on the annual operation data of a large number of systems. The analysis is focused on the primary energy factor of the heat supplied to the final users, as well as their CO_2 emission factor, to be used as a reference in comparison with other heat generation technologies.

Whereas reference values are already available in literature, this work aims at highlighting the variability of the values and its main drivers. Such information is essential for the development of energy planning studies that need to consider sensitivity analyses on different types of DHS. The use of real operation data rather than design or nominal values ensure that the results include the anomalies and issues that commonly affect the generation plants (e.g. variable performance, maintenance issues, etc.).

2.2. Description of the case studies

This work is based on the operational data of several DHS in Italy, including different sizes, users types, generation technologies. The data are collected by AIRU, the National Association of DHS Companies [31]. The results of this work are based on the detailed analysis of 140 DHS on a total of 182, which however represent around 92% of the

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