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Impact of district heating and groundwater heat pump systems on the primary energy needs in urban areas

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ABSTRACT

This work is focused on the planning of rational heating systems for urban areas.

From the sustainability viewpoint, district heating is an important option to supply heat to the users in urban areas. The energy convenience of such option depends on the annual energy request, the population density and the efficiency in heat production. Among the alternative technologies, geothermal heat pumps (both open loop and closed loop heat pumps) play a crucial role.

This paper aims to propose a procedure to select which users in an urban area should be connected with a district heating network and which ones should be heated through an alternative technology, in order to reach a globally optimal system from the energy viewpoint.

The procedure proposes district heating as the initial choice for all the users. The users are then progressively disconnected to the network, according with the primary energy required to supply them heat, and the alternative technology is considered for disconnected users. Here, ground water heat pump is considered as the alternative technology. The total primary energy request is assumed as the objective function to be minimized. To reach this result, the exergetic cost of heat supplied through heat pumps system must be evaluated. Such evaluation is not trivial, as it must include proper analysis of both the district heating network and the alternative system. In the case of densely populated areas, an additional consideration is necessary: the subsurface thermal degradation caused by heat pump installations may affect the performances of surrounding installations. This impact is calculated through a thermo-fluid dynamic model of the subsurface.

The application to an Italian town is considered as a test case. The optimal configuration of the overall urban heating system is obtained. This configuration corresponds to the minimum primary energy request to supply heat to all the users (those connected to the network and those using an alternative heating system).

1. Introduction

District heating is a rational way to supply domestic heating and hot tap water to buildings in densely populated towns, especially in areas with continental climate. District heating networks (DHNs) are generally fed by cogeneration power plants, biomass boilers and other renewable energy systems, industrial process heat recovery systems. These systems are often designed to cover base load in order to operate with high utilization factors and thus reduce the payback period. For this reason, pick loads are covered using boilers.

District heating systems have to compete with distributed cogeneration and heat pumps. These options are particularly interesting in the case of areas with smaller population density, where district heating becomes economically and energetically expensive. In particular, heat pumps have great potential of application [1]. Trade off between technologies depends on various parameters: energy and power density (i.e. energy request and power request per unit ground surface), distance from the potential thermal plant, etc. A trade-off analysis between multiple technologies is presented in Ref. [2], while comparisons between district heating and alternative technologies for a specific user are proposed in [3–5].

To analyze the conditions that make district heating or an alternative technology the most rational choice, an optimization technique is applied in this work. The objective consists in

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