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Sustainable urban heat strategies: Perspectives from integrated district energy choices and energy conservation in buildings. Case studies in Torino and Stockholm

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ABSTRACT

Heat demand in buildings is responsible for a large portion of energy loads in Europe, and building renovations represent an important opportunity to achieve sustainability objectives. Efficient district heat (DH) can represent a cost-effective heat source for buildings. Yet, building heat demand reductions will have implications on sustainable DH production and operation. Analysis is therefore needed to identify cost-effective strategies for low-carbon heat solutions in integrated energy systems.

This paper proposes a methodology to investigate different scenarios to 2050 involving integrated heat supply and building envelope investment choices in Torino, Italy and Stockholm, Sweden. The goal is to provide an overview of opportunities for decision makers in elaborating heat strategies including DH.

Results show that opportunities exist to achieve consistent energy savings and emissions reduction through strategic combination of DH and building renovation investments.

A systems approach is essential to avoid unnecessary investments or early retirement of assets: building renovations should be planned carefully as lower DH base loads could lead to increased running costs, and DH investments need to be adapted to long-term building improvements. Reduced peak loads can allow increased use of low-grade heat, higher merit-order power generation and in some instances cost-effective expansion of DH.

1. Introduction

Europe has set forth ambitious targets to cut carbon emissions by 40% and 80% compared to 1990 levels by 2030 and 2050, respectively [1]. Each sector will play a role in achieving the required energy transition to meet those goals, and the European Commission assessed that green-house gas emissions related to the building sector could be reduced by around 90% compared to 1990. With respect to other sectors, higher targets have been assigned to buildings as around 40% of European buildings pre-date the 1960s, where their energy savings potential is high [2].

The energy efficiency potential in buildings is enormous. Globally, more than 30% of total final energy consumption occurs in buildings, and assertive action to improve building energy performance could limit global building energy demand to 2050 at just above 2013 levels [3]. An estimated 60% of global building final energy demand today is in urban buildings. Solutions to improve building energy performance in the urban built environment are therefore a key driver for meeting a more sustainable future.

In most European countries, space heating is the largest energy-consuming end use in buildings. Measures to improve the thermal energy demand in buildings will therefore be critical to reducing building energy demand and related emissions. To date, regulations for high-performing new buildings (e.g. near-zero energy buildings [nZEBs]) have been strongly enforced by the European community [4] and by national governments. However, building renovation standards for improving the energy performance of existing buildings – the largest share of the European building fleet – have been less promising; although some countries in the European Union (EU) have made good progress in this area.

Other possibilities for meeting EU sustainability goals include the improvement of heat generation efficiencies. For areas with

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high heat densities, district heat (DH) may represent an interesting solution since it can take advantage of local excess heat and renewable energy sources, as well as high-efficiency heat generation technologies such as combined-heat and power (CHP). Benefits related to the development of DH networks can be found in the work of [5]. Moreover, it has been recognized that heat demand in Europe is sufficient for promoting the development and expansion of DH systems [6].

It is plausible to assume that in areas where DH is already present or is planned, variation in thermal demand will occur as building energy efficiency improves over time. Two main deliberations can be considered: (i) at a certain point, energy efficiency measures in buildings will stop being cost-effective relative to the cost of heat, and (ii) variation of thermal demand will impact the operation and generation strategies for DH and could influence any new investment strategies.

Finding synergies between energy efficiency strategies in building renovation and DH supply has been identified as fundamental for the success of urban heat strategies [3]. In cities with existing DH networks, this effective synergy is central [7]. In fact, while energy savings obtained from DH network extensions seem an attractive solution from an energy and environmental perspective, finding economically viable solutions is still a challenge [8].

Limited studies have tried to investigate, from a system perspective, the possible synergies and methodologies to support a holistic approach to building renovation and DH investments or expansions. The study of [9] analysed to what point buildings could be refurbished, taking into account DH utilisation and electricity production. Similar analysis by Ref. [10] assessed that with a "greener" heat production mix, the benefits of building thermal demand reduction decrease [11]; verifies that for both an economic and an environmental perspective, the reduction of electricity consumption needs to be prioritised with respect to savings in DH. Research by Refs. [7] and [12] confirmed the importance of electricity savings [13]. studied how several renovation measures in buildings affect the CO_2 emissions under different system perspectives [14]. analysed the combined effects of building renovation in DH systems, finding that if co-produced electricity replaces electricity from coal-fired condensing power plants, a 20% heat demand reduction is optimal for the Swedish energy system. In Denmark [15], identified a 50% decrease in net heat demands of new buildings or buildings that need to be renovated as a suitable strategy when 2/3 of heat is provided by DH and 1/3 by individual heat pumps. Results from Ref. [16] showed that combing building renovation with the expansion of a DH network improves the overall fuel efficiency of the system.

From previous studies, it is clear that the system dependency of energy savings still needs to be better understood. This research presents a methodology for supporting local authorities, researchers and utilities in investigating the impacts (in terms of energy, emissions and costs) of several market strategies involving different building renovation measures and new technological investment choices over long-term horizons in cities with DH. The novelty of the approach consists of the integration of both buildings and DH sectorial models through an integration module to develop long-term explorative scenarios. Compared to previous methods, this approach allows a comparison of the energetic, environmental and economic impacts of several demand/supply measures over long-term horizons, using a "matrix" of potential combinations of building renovation measures with DH investments. In particular, the approach has been developed considering the typically available data in Europe, and it pulls upon GIS software (typically used in planning activities), building simulation and district heating network simulation models. This approach allows for a more comprehensive energy system analysis, typically applied to larger scale with specific software (e.g. EnergyPLAN [17]), by guarantying the sufficient level of detail, particularly in terms of demand disaggregation, necessary for local applications. The methodology does not seek to replace other simulation or complex energy system modelling platforms but rather to generate suitable indices through the combined methodology upon which sound and informed decisions can be made regarding the appropriate direction for investments with respect to aforementioned objectives.

In this paper, the proposed integrated methodology is applied to two case study cities with extremely different characteristics in terms of building archetypes and district heating systems, but with comparable populations: Torino in Italy and Stockholm in Sweden. The case studies scenarios analysis involved the cooperation of local utilities to support the technological choice for defining the configuration of the DH systems. Section 2 describes the case studies to which the methodology has been applied. Section 3 explains the details of the methodology, and Section 4 is dedicated to the results. Section 5 summarises the main conclusions and insights derived from the proposed research.

2. Description of the case studies

The methodology has been applied to two very different cities: Torino, Italy and Stockholm, Sweden (Fig. 1). This choice is justified by the interest in comparing two DH cities representative of different geographic situations, demand contexts, technical opportunities and DH challenges, respectively of southern and northern Europe in the two case study cities. The main differences are related to the building types (high insulation level in Stockholm and low insulation levels in Torino), DH system (district heating connections almost saturated in Stockholm and large expansion possibilities in Torino) and climate (cold climate in Stockholm and continental climate in Torino). This choice also provides a wider overview and more informed assessment of integrated building and DH solutions.

Torino is sited in the continental climatic zone (2617 heating degree days [HDD] at 20 °C) and has approximatively 900 000 inhabitants living in roughly 36 000 residential buildings. The building stock of Torino has been fully characterized in terms of building types, heated volumes and energy consumptions using GIS tools in the works of [18–20]. The total urban volume entails 213

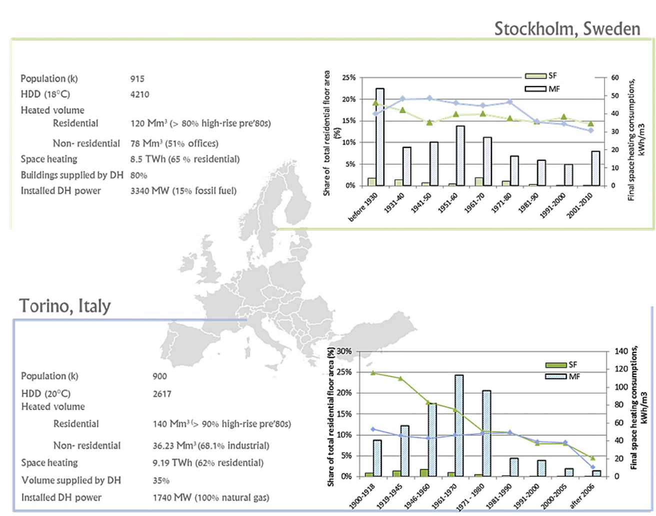

Fig. 1. The case studies: Torino and Stockholm. SF = single families; MF = multi-families.