Sustainable Cities and Society 23 (2016) 23–36

Contents lists available at ScienceDirect

Sustainable Cities and Society

journal homepage: www.elsevier.com/locate/scs

Analysis of the electricity consumptions: A first step to develop a district cooling system

Luca Pampuri [a], Nerio Cereghetti [a], Davide Strepparava [a], Paola Caputo [b,*]

[a] *Istituto di Sostenibilità Applicata All'ambiente Costruito, Scuola Universitaria Professionale della Svizzera Italiana, Campus Trevano, Via Trevano, CH-6952 Canobbio, Switzerland*

[b] *Architecture, Built Environment and Construction Engineering Department, Politecnico di Milano, Via Bonardi 9, 20133 Milano, Italy*

A R T I C L E I N F O

Article history:
Received 23 December 2015
Received in revised form 17 February 2016
Accepted 18 February 2016
Available online 26 February 2016

Keywords:
District cooling
Electricity consumption
Energy consumers
Clustering
Energy signature
GIS

A B S T R A C T

Space cooling represents an increasingly and often understated important energy demand even in moderate climates. Usually space cooling is provided at building level by electric driven appliances. This implies several problems in summer due to the peak of electricity consumption.

Analytical methods for investigating energy consumption due to space cooling demand at urban or regional level are needed. The research here reported is focused on the territory of southern Canton Ticino, in Switzerland, and is based on real data provided by the local electricity company. The research investigates the electricity consumptions of big users in order to verify if there is a significant cooling demand, how this demand affects electricity consumptions and if this demand can be satisfied by district cooling (DC). The possible DC connections were selected by a defined procedure and mapped by GIS, as well as the density of the electricity consumption and the peak power. Three main areas suitable for DC were identified. The analysis demonstrates that DC could represent an alternative to electric driven air conditioning systems, with benefits for the consumers, the utilities and the environment.

1. Introduction

The path to carbon neutral communities represent long lasting and urgent challenges for all governments. For example, the EU has approved the "Roadmap for moving to a competitive low carbon economy in 2050" (EU COM112/2011, 2011) with the objective to reduce greenhouse gas emissions by 80–95% by 2050 in comparison to those of 1990. Analogously Switzerland has approved the Energy Strategy 2050 that includes the main aims for the energy policy towards 2050 (BFE, 2015). Among these aims, as consequences of abandoning nuclear power, a reduction of the electricity consumption is required.

Energy statistics show that European and Swiss buildings are responsible of more than the 40% of the total final energy consumption (Odyssee, 2012; BFE, 2015), representing an important energy saving opportunity. More in details, energy statistics show that buildings space heating accounts for 68% and 71% of end-use energy consumption respectively in Europe and Switzerland, while lighting and electrical appliances account for 15%, water heating for 12% and cooking for 4% (Odyssee, 2012; BFE, 2015).

Despite the energy efficiency measures developed in Europe and in Switzerland, the global energy consumption in buildings continues to rise. In particular, considering the focus of the present paper, BFE (2015) stated that energy consumption related to air conditioning had increased of 39% from 2000 to 2013. Many authoritative researches have investigated space cooling in terms of predicting cooling loads in buildings, but a significant level of complexity is recognized in this framework as reported also in Damnu, Wanga, Zhai, and Li (2013). The present research suggests another approach, that starts from the available electricity consumption, since space cooling demand is usually provided by compression chillers. The increasing of the electricity demand due to space cooling is in contradiction with the defined energy targets, as empathized also by the media during the hot summer of 2015 (IEA, 2015).

In general, it is difficult to obtain reliable data about electricity consumption for a large number of users (Caputo, Costa, & Zanotto, 2013). Furthermore, with few exceptions, these data are available as a whole, without the details of electricity consumption for cooling demand. The evaluation of the summer surplus due to space cooling is difficult because often data do not cover a full year and significant sample of users. For these reasons, a methodology for analyzing this hidden energy demand and for studying how it can be satisfied without affecting electricity consumptions was

* Corresponding author. Tel.: +39 0223999488; fax: +39 0223999484.
E-mail address: paola.caputo@polimi.it (P. Caputo).

http://dx.doi.org/10.1016/j.scs.2016.02.015
2210-6707/

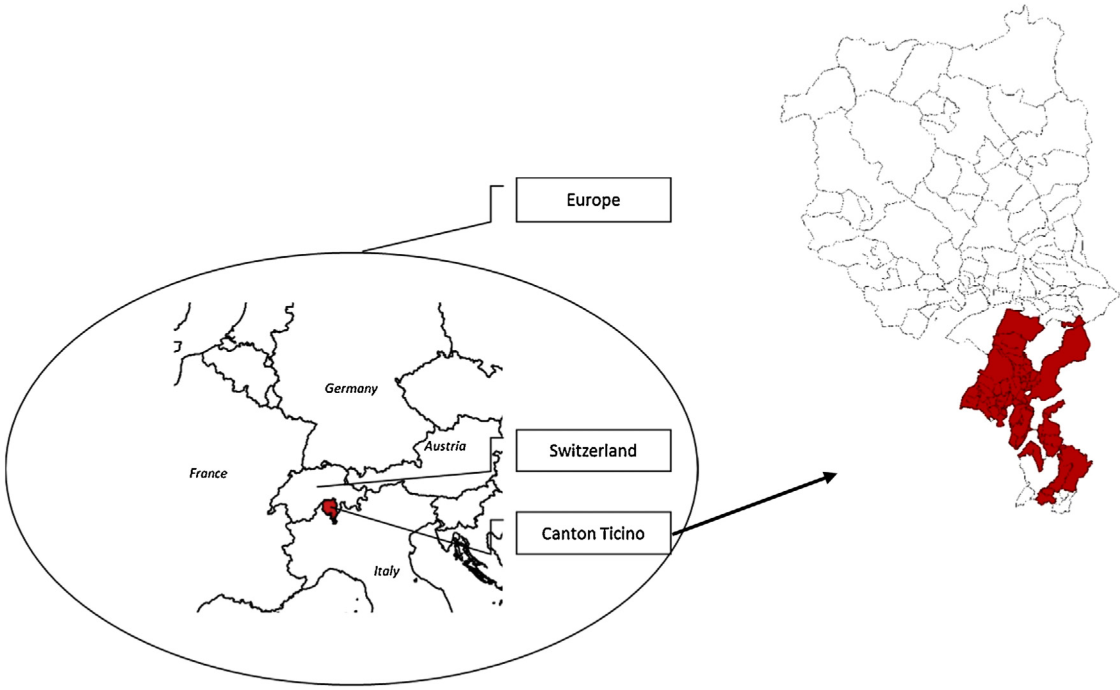

Fig. 1. Territorial context of the study (left) and map of municipalities supplied by AIL (in red) in Canton Ticino (right). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

developed. The present paper reports the results of a research conducted on the territory of southern Canton Ticino, in Switzerland (Fig. 1). Even though this territory is small, it can be considered representative of a large arear with similar climatic and morphological conditions. The research starts from the analysis of real data provided by the local electricity company (AIL SA, 2015) that supplies electricity to most of southern Canton Ticino (Fig. 1). Following the methodology reported in Section 3, the research investigates the electricity consumptions of big users in order to verify how space cooling affects electricity consumptions and if it can be satisfied by district cooling (DC). The analysis demonstrates that, despite the temperate climatic conditions, there is a significant consumption of electricity due to the space cooling demand, especially in the tertiary sector and that DC can be an efficient alternative to conventional cooling devices.

2. District cooling as an alternative to conventional cooling devices

El Barky and Dyrelund (2013) report an interesting summary about the advantages of moving from conventional space cooling devices, chillers operating at building level, to DC. The operation of electric chillers implies large investments in power peak plants and even for blackouts in many cities around the world. A light reduction of the peak demand can be achieved in high thermal capacity buildings, by other measures and users behavior, not always applicable.

In case of proper morphologic, climatic and density features of the built environment, DC can be adopted as an alternative to conventional cooling devices. As well explained by El Barky (2013), DC can bring advantages similar to those of district heating (DH) due to centralized production (i.e. risk reduction for the individual consumers and cost effectiveness for the energy supply companies). DC can contribute to use local sources that otherwise would be wasted.

Euroheat and Power (2006) reports that DC is normally produced by means of one or more of the following technologies that can be also combined:

- conventional compressor-based cooling;
- absorption cooling, transforming waste heat into cooling;
- free cooling, using cool ambient air or cool water from the ocean, lake or river.

Euroheat and Power (2006) affirms that a DC system can reach efficiencies typically 5 or even 10 times higher than the efficiencies of electric chillers, as it is shown also in Table 1, where primary resource factors (PRF) are adopted. Primary energy refers to energy that has not been subjected to any conversion or transformation process (e.g. oil in the oil fields). Primary energy may be resource energy or renewable energy or a combination of both. Resource refers to a source depleted by extraction (e.g. fossil fuels) and renewable energy to a source that is not depleted by extraction (e.g. biomass, solar). The use of the primary resource factor (PRF) enables to measure the savings and losses occurring from energy generation to the delivery to the building. The primary resource factor expresses the ratio of the non-regenerative resource energy required for the building to the final energy supplied to the building. The primary resource factor represents the energy delivery but excludes the renewable energy component of primary energy.

Since southern Canton Ticino has several natural sources suitable for DC such as the Lake of Lugano and several local rivers, free cooling (i.e. the adoption of cold water for cooling purposes) could be the most appropriate technology in this case.

2.1. District cooling potential in Europe and Switzerland

DC still represents an uncommon technology for providing cooling. For example, the current DC market share represents only 1–2% of the cooling market in Europe and DC is almost not adopted in Switzerland. Despite of this, there are interesting examples in Asian and European cities (IEA, 2015; Xiang-li, Lin, & Hai-wen, 2010), i.e. Stockholm, Helsinki etc.

Euroheat and Power (2006) estimated that the European cooling market would be around 660 TWh/y in the period 2012 to 2020. This corresponds to an electricity consumption of 260 TWh,