Energy Policy 113 (2018) 223–231

Contents lists available at ScienceDirect

Energy Policy

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

Estimation of European Union service sector space cooling potential

Mindaugas Jakubcionis*,[1], Johan Carlsson

European Commission, Joint Research Centre, Directorate for Energy, Transport and Climate, P.O. Box 2, NL-1755 ZG Petten, Netherlands

ARTICLE INFO

Keywords:
Space cooling
Service sector
Cooling demand
Energy system
Climate

ABSTRACT

Data on European service sector space cooling demands are scarce and often of poor quality. This article estimates the potential space cooling demands in the service sector of the EU using the United States as a proxy. Since the space cooling demand in the US is mature and nearly saturated, this provides useful insights of potential future European space cooling demand. A georeferenced approach based on comparing Cooling Degree Days and space cooling consumption in the USA was used to establish the potential service space cooling demand in NUTS-3 regions of EU. The total potential space cooling demand of the EU was estimated to be 174 TWh for the service sector in an average year. The estimated potential of space cooling demand, identified in this paper for all EU Members States, could be used while preparing the next iteration of EU Member States' Comprehensive Assessments related to the Article 14 of the Energy Efficiency Directive or other energy related studies.

1. Introduction

The space cooling demand in the Member States of the European Union is often not well established. This was concluded from a review of the Comprehensive Assessments of the energy efficiency potentials in the heating and cooling sector performed by EU Member States under Article 14 of the Energy Efficiency Directive (European Parliament, 2012). Out of 28 Member States, eight estimated their cooling demand for the residential sector and fifteen for the service sector. Similarly, the energy balances of Eurostat do not monitor energy use for cooling. This is due to the fact that most space cooling is provided by electric air-conditioned units and while European statistics on electricity consumption in different sectors is available, it does not differentiate how the electricity is used, e.g. for cooling or other purposes. The lack of knowledge of the current and projected cooling demand is an obstacle for many Member States when designing their policies.

There are several policy initiatives to improve energy efficiency in buildings, e.g. the Energy Performance of Buildings Directive (EPBD). The EPBD requires that new buildings and old refurbished buildings will be near zero energy buildings by 31 December 2020. Member States have to ensure that energy performance of buildings is set at cost-optimal levels. To decarbonise the energy system, the heating demand has to decrease significantly, since heating and cooling is about half of the primary energy consumption. With regard to cooling, the requirement of cost-optimisation might at first not affect the trajectory much since it is a small share of the cost for the society today. Hence, in this phase improving thermal insulation of windows and walls might actually increase cooling demand. Gradually, as cooling demand increases, the efficiency measures to slow cooling demand become vital, e.g. shading, passive cooling. As was discussed by Aebischer et al. (2007) the effect of insulation improvement on cooling demand will depend on many factors. The probability of overheating increases as more heat is trapped inside buildings, but contrarily proper operation modes of ventilation systems can mitigate potentially negative impacts from more insulated buildings. Due to the uncertainty about the trajectory for cooling demand, this study aims rather at setting a ceiling for the cooling demand.

Several studies have been performed on the present cooling demand and a few on future cooling demands (Pardo et al., 2012; Werner, 2016). Different methodologies were used and the variety of estimates was often substantial, which underlines the uncertainties involved. This paper employs a comparative method for estimating the potential cooling demand in the service sector of the EU by using the USA data as a proxy. It employs a geo-referenced approach to establish a relationship between the cooling demand and the number of cooling degree days in 3141 counties of the US. This relationship is then used to provide an estimation of potential cooling demand in 1335 NUTS-3 regions of the EU using their number of cooling degree days as the input parameter.

Space cooling in the USA is more common in all the sectors of the economy compared to the EU. Consequently, the US authorities have analysed space cooling in greater detail compared to the EU. The space cooling demand in the EU and the US differs due to warmer climates, different habits concerning comfort levels for cooling, and possibly

* Corresponding author.
E-mail address: mindaugas.jakubcionis@ec.europa.eu (M. Jakubcionis).
[1] The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

https://doi.org/10.1016/j.enpol.2017.11.012
Received 2 May 2017; Received in revised form 30 October 2017; Accepted 5 November 2017
Available online 21 November 2017
0301-4215/

diverse thermal characteristics of buildings. Nevertheless, as study shows, energy performance of building elements in USA and EU are of comparable levels, although regional differences do exist as it can be expected taking into account climate diversity within such large territorial entities as EU and USA. Therefore, this study is based on the assumption that under the same climatic conditions the building energy performance would be of the similar level in the USA and the EU.

This paper has the following structure: (1) description of the methodology used, (2) description of the current space cooling demand in the EU, (3) determination of service sector space cooling indicators based on data from the US service sector, (4) description of climatic conditions of EU and determination of potential cooling demand in the EU Member States, (5) impact of potential service sector cooling demand on energy systems of EU countries, (6) Comparison of energy performance of USA and EU building stock, (7) uncertainties and method limitations, and finally (8) conclusions and policy implications.

2. Methodology

2.1. General methodological considerations

The overall objective of this article is to determine the space cooling potential in the service sector of the European Union. The service or tertiary sector is very heterogeneous. It includes subsectors such as offices, hotels, restaurants, wholesale and trade, education, recreation and so on (Pardo et al., 2012). In turn, these subsectors can further be subdivided into branches. Offices can be subdivided into private and public, trade establishments into small shops (often located on the ground floor of residential buildings), supermarkets and shopping malls. Each of these branches might possess different characteristics, such as energy intensity or average size.

Comparison of data from different sources is complicated due to dissimilar decompositions of the service sector. For instance, Pardo et al. (2012) presents space cooling data on 5 subsectors: hospitals, hotels and restaurants, sports and recreation, shops (large and small) and offices. The study of Werner (2016) defined the service sector as consisting of all buildings excluding residential, industrial and agricultural buildings.

In this article decomposition of service sector is based on the Statistical Classification of Economic Activities in the European Community (NACE).[2] In the context of this study, the service sector is comprised of NACE sections G to U, including such activities as wholesale and retail trade, accommodation and food service, education, healthcare and so on. A survey on energy consumption in the service sector performed by US Energy Information Administration (USEID, 2016) was used as a main source of information about cooling demand in USA service sector. Its decomposition is comparable to the NACE system.

The methodology used in this paper is similar to the methodology applied by the authors in their paper dealing with cooling demand potential in the residential sector of EU (Jakubcionis and Carlsson, 2017). However, significant changes to the methodology were necessary due to, first of all, differences in composition and characteristics of residential and the service sector and, second, the availability of data. In general, data on the service sector is scarcer and of lower detail compared with the residential sector. The methodological steps of the analysis are presented in Fig. 1. The activities from Fig. 1 are explained in more detail in the following sections.

2.2. Space cooling indicators using data on USA

In order to determine the relationship between space cooling demand and climatic conditions, cooling degree day (CDD) values were calculated for 834 metrological stations located across USA territory. The cooling degree day is the most commonly used climatic indicator of the cooling demand. It is a measure of the average temperature departure from a set base temperature (Isaac and van Vuuren, 2009) and is widely used when describing relationship between space cooling demand and climatic conditions (Kemna and Acedo, 2014). Cooling degree days are calculated as an accumulated temperature difference above a base temperature. The base temperature in this study was set at 18 °C both for USA and EU cases.

The CDDs in the USA were calculated using daily temperature information, derived from databases of US Historical Climatology Network (Menne et al., 2015). Mean CDD values were calculated for each meteorological station as a 20 year average for annual CDDs (1995–2015) and imported into a GIS map of USA. A raster surface was generated through using an inverse distance weighted (IDW) interpolation from GIS Spatial analysis tools. This interpolation method assumes that the mapped variable (mean CDD values of different weather stations in this case) decreases in influence with the distance from its sampled location. The resolution of the resulting raster was 1 km^2. It was joined with the administrative map layer of USA counties (USCB, 2015) using GIS Spatial join tool. This allowed establishing CDD values for each county in mainland USA, 3141 counties in total.

Cooling demand intensity $I_{cooling}$ and cooling penetration *PNT* were calculated for the census and climatic regions using data from the US Energy Information Administration (USEID, 2016) database, which contains information about electricity energy intensity for cooling in service sector buildings in different regions as well as other information related with cooling consumption in different types of service buildings. Final energy consumption was recalculated into useful cooling demand based on assumed seasonal energy efficiency ratio (SEER) values of 3.1.

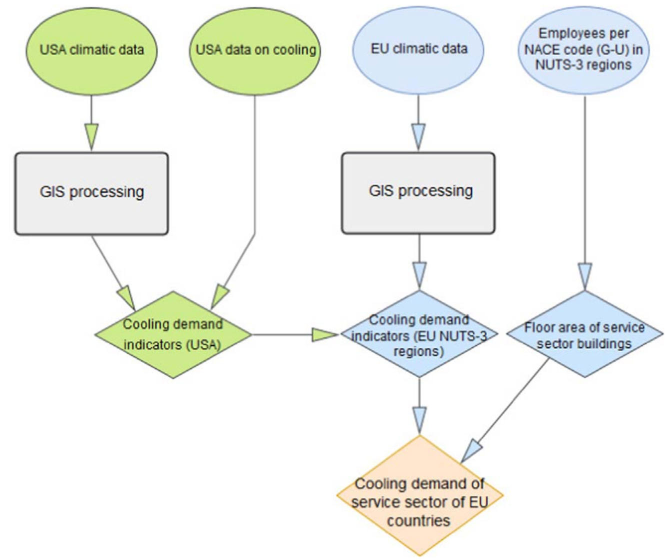

Fig. 1. Successive activities performed during analysis presented in the article.

2.3. Estimating service sector space cooling demand potential in EU

Mean CDD values for EU were calculated for 894 meteorological stations, located throughout EU and neighbouring countries, such as Norway, Switzerland, Russia etc. for the years 1995–2015, using European Climate Assessment and Dataset (Klein Tank et al., 2015). Mean CDD values for all the Member States were determined using GIS tools following the same procedure as for USA.

The European service sector space cooling demand potential was estimated for 1335 NUTS-3 regions based on cooling indicators determined from data from the service sector in the USA. The following formula was used:

[2] http://ec.europa.eu/competition/mergers/cases/index/nace_all.html.