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European space cooling demands

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ABSTRACT

Information about European space cooling demands is rare, since cooling demands are not properly measured, when electricity is used for operating space cooling devices. Cooling demands are only measured at deliveries from district cooling systems. However, information about cooling demands by location and country is required for planning district cooling systems and modelling national energy systems. In order to solve this cooling information dilemma, space cooling demands have been assessed for European service sector buildings. These estimations were based on cold deliveries from twenty different European district cooling locations in eight countries. Main findings are that (1) the estimated specific cold deliveries are somewhat lower than other estimations based on electricity inputs and assumed performance ratios, (2) aggregated space cooling demands are presented by country, and (3) an European contour map is presented for average specific space cooling demands for service sector buildings.

1. Introduction

More and more European buildings are provided with space cooling in order to obtain comfortable indoor climates during warm and hot summer periods. By 2025, the installed cooling capacity is likely to be 55–60 percent higher than the 2010 capacity [1].

However, information about European space cooling demands are rare with respect to specific cooling demands and proportions of building floor areas having space cooling by country. Neither do national energy balances contain any specific information about cooling demands for residential and service sector buildings. This information is needed for proper future modelling of the European energy system, since space cooling becomes more significant as space heating demands will be reduced from active energy efficiency measures and from climate change. Information about space cooling demands is also required in impact assessments of the European Energy Performance of Buildings and Ecodesign Directives. According to article 14 of the EU directive on energy efficiency from 2012, EU Member States shall also carry out and notify to the Commission a comprehensive assessment of the potential for the application of district cooling before the end of 2015. This can be difficult to accomplish when the aggregated cooling demands are not known.

In order to further explore the current European space cooling demands, an overall study was included in the work programme of the Stratego project [2], financed by the 2013 call of the IEE (Intelligent Energy Europe) research programme. This paper is a summary of this work concerning specific and national space cooling demands. The Stratego assignment was to estimate the current cooling demands in European buildings by country and by location by a bottom-up method for planning and modelling purposes. Another specific purpose was to provide input for creation of a detailed cold density map for Europe in order to identify possibilities for district cooling systems.

By tradition, cooling supplies as output from cooling devices are seldom measured, making it difficult to estimate the actual cooling demands in buildings. This statement is also valid for the electricity supply used as input to those cooling devices. This electricity supply for space cooling is normally just a part of all electricity delivered and measured to a building.

Some information about cooling demands in Europe have been published, but many of these published demands are not measured, but instead theoretically estimated by combining climate data with standard efficiencies for cooling devices. Hence, gathering existing cooling demands in Europe is not an easy task and a proper Pan-European survey of cooling demands and supplies by countries and by locations based on measurements has never been published.

However, one exception exists with respect to measurements of cooling supplies. When district cooling systems are used, the cooling supplies are regularly measured in order to create invoices

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for these cold deliveries. Hereby, these systems can provide information about aggregated and average cooling demands. However, these systems deliver cold mostly to service sector buildings and provide no information about space cooling demands in residential buildings. The main research idea behind this paper was to use actual measured deliveries of district cooling at various locations for estimation of average European space cooling demands for service sector buildings.

The following three research questions were identified for the analysis:

1. Is it possible to gather measurements of district cooling deliveries from various climate regions to estimate specific space cooling demands in European service sector buildings?
2. Can national space cooling demands be assessed from estimated average space cooling demands and gathered cooled floor areas?
3. How will the assessed aggregated and national space cooling demands within the European Union correspond to other recent estimations?

The main delimitation is that only space cooling demands for getting lower indoor temperatures in residential and service sector buildings during summers are considered. Other cold demands in buildings, such as refrigerators or freezers, are excluded in these estimations. Neither industrial cooling systems nor automotive air conditioning are included. All estimations consider the 2010 situation or conditions close to this reference year. The findings can be used as indicative values when designing cooling systems, but should never replace traditional design routines, since the findings are targeted for aggregated planning and energy modelling purposes.

All cooling demands and supplies are here expressed as useful cold to be used inside buildings, except when otherwise is clearly stated. Cold is defined as heat removal. This cold use interface is equivalent to cold deliveries from chiller evaporators or from district cooling systems. Hereby, cooling demands and supplies are not generally expressed as electricity input to chiller compressors.

2. Background

The Ecoheatcool project, performed during 2005 and 2006 within the IEE programme, had the ambition to estimate European space heating and cooling demands. Because of lack of proper input data, the EHI (European Heating Index) [3] and the ECI (European Cooling Index) [4] were instead introduced in order to show the distribution of the specific heating and cooling demands in Europe. These two indices were estimated in conjunction with each other and based on traditional heating and cooling degree days with adjustments for expected heat resistances in typical building envelopes used in various countries. The heat resistances were assumed to be proportional to the square root of the heating degree days, since insulation thicknesses are optimised concerning the heat demands. These adjustments were necessary since the applied heat resistances determine the indoor temperature additions from both internal and external gains in the building heat balances. These temperature additions decrease the heat demands and increase the cooling demands. The developed methodology with chosen threshold temperatures has been presented in Ref. [5]. The European EHI and ECI maps have also been reproduced in Ref. [6]. Simple national EHI and ECI values were estimated by linking to each capital city in each country, since the capital city region populations dominate the national populations in most countries. These simplified national ECI values were used in this study.

No summary of measured output from cooling devices with respect to location have been found in international energy literature. Three major summary sources concerning electricity input for cooling devices in service sector buildings have been identified. The first is the EECCAC study from 2003 [7], containing average estimations for the former EU15 countries. The second source is a 2007 conference paper concerning impact of climate change on thermal comfort [8]. This paper provides nine estimates for eight European cities. The third source is a FP7-project called INSPIRE, which in 2014 published a summary of national averages for residential and office buildings in the EU27 countries [9]. Corresponding national information have been published for three countries: Netherlands [10], Sweden [11], and France [12].

Aggregated information about European space cooling demands has been published by four different sources. The first is the 2012 report from the Joint Research Centre of the European Commission concerning heat and cooling demands and corresponding market perspectives for the EU27 countries [13]. This study reports the total 2009 space cooling demand to be 398 TWh cold, thereof 374 TWh in the service sector. However, the corresponding methodology paper [14] reveals that also the electricity inputs for operation of ventilation systems were added in the estimation of cooling demands, because of a direct transfer of information from the basic source of [15]. If this questionable addition is removed, the revised 2009 cooling demand becomes 204 TWh cold, thereof 180 TWh in the service sector. The second source is the 2014 conference presentation from EURAC [16], giving the estimate of the electricity input for cooling in EU27 to be 82 TWh electricity, thereof 64 TWh in the service sector. These electricity inputs can be converted into cold outputs by using the SEER (Seasonal Energy Efficiency Ratio), which is a performance indicator for cooling devices defined as the ratio between the annual cooling output and the annual electricity input. With a SEER value of 3.1, later estimated in this paper, this second estimate becomes 254 TWh cold, thereof 198 TWh in the service sector. The third estimate comes from a 2014 report [17] from the IEE-project called RESCUE, giving the total EU27 space cooling demand to be 285 TWh cold in 2012, thereof 228 TWh in the service sector. The fourth source comes from an impact assessment for the European Ecodesign Directive [18], giving the total EU27 space cooling demand of 220 TWh cold in 2010, thereof 164 TWh in the service sector.

The common denominator for the first, second, and forth estimations of aggregated cooling demands is that they have been based on electricity inputs to cooling devices together with assumed SEERs. The RESCUE estimate was obtained from the total potential cooling demand of 1220 TWh, based on specific cooling demands proportional to ECI, and assumed proportions of cooled building floor areas of 8 percent for the residential sector and 41 percent for the service sector. Hence, all these four estimates on aggregated EU space cooling demands were based on assumed input variables and not on real measurements.

The cold currently generated for space cooling can either be generated in each room by individual cooling devices (room air-conditioners – RAC) and is mostly used in residential buildings, by central cooling (central air-conditioning – CAC) in each building and is mostly used in service sector buildings, or by district cooling systems in dense urban areas. More detailed information about RAC and CAC systems in the aggregated European cooling market is provided by Refs. [19–22]. An overview of the presence of European district cooling systems has been provided by Ref. [6]. An example of an analysis of cooling demands in a major city is presented for London in Ref. [23]. A detailed analysis of all cooling demands in a country is provided for Germany in Ref. [24].

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