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Heat Roadmap Europe: Identifying local heat demand and supply areas with a European thermal atlas

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ABSTRACT

In 2016 the first Strategy for Heating and Cooling of the European Union has shown that district heating and cooling networks can integrate renewable energies in an increasingly energy-efficient built environment. At the same time, the heating and cooling sector is probably the most diverse and least mapped component of the European energy system. The aim of the Pan-European Thermal Atlas is to improve the knowledge base for the geographical distribution of heat and cooling demands across Europe. Demand densities of the demanded thermal services themselves, the spatial coherence of these demands, and their location relative to sources of heating greatly affect the economy of district heating schemes compared to individual solutions. The objective is therefore to develop a comprehensive model, which can be used to a) quantify heat demands by density, b) group coherent areas with demands into prospective supply zones, c) produce supply curves for these zones, and d) ultimately calculate local energy mixes on the basis of allocated excess heat as well as renewable energy sources. The developed method spatially disaggregates national demand data to high-resolution geospatial data on urban structures. The resulting atlas allows for an advanced quantitative screening process, which can establish the basis for energy systems analyses relying on geographically explicit information on the heating demand and supply volumes and costs. The present paper presents version 4 of the Pan-European Thermal Atlas, which takes another step towards higher spatial resolution and confidence in comparison to its predecessors, version 1 to 3. For the first time, a 100 m resolution heat atlas of Europe is being presented, which may help describing the heating sector in the required spatial resolution. By means of spatial statistical analyses using ordinary least square linear regressions, multiple spatial inputs such as population, degree of built-up and its derivatives are turned into a coherent model of the urban tissue. Plot ratios form the basis of models of heat demand in single and multi-family residential buildings as well as the service sector. Prospective district heating areas have been delineated, and the resulting zoning of heat supply has been linked to a resource-economic analysis, which allows for cost-supply studies in disaggregated form. The present heat atlas version 4 is now available for 14 countries that altogether represent 90% of the heat demand in the 28 European Union member states. First results are being presented with emphasis on the achieved methodological improvements. Moreover, a newly developed online mapping system is being presented, which will assist in mapping the new geography of heating and cooling demands and supplies.

1. Introduction

In its Heating and Cooling Strategy published in February 2016, the European Commission (EC) [1] put attention to the heating and cooling sectors of Europe, which stand for more than 50% of the total final energy demand in Europe [2]. Heating and cooling supply had received little attention until then [3], with few and mostly national or regional policies, plans and strategies but without

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integrating various sectors such as buildings, transport and industry, which will help to incorporate larger amounts of renewable energy [4]. Also, only a few countries currently have dedicated policies that regulate heat demand and supply. Main emphasis is on improving the building performance, either through deep renovation or the gradual replacement of the building stock with zero-energy buildings [5]. However, strategies to achieve a significant reduction of greenhouse gas emissions, import reliance and costs by means of combined demand and supply sector efficiency measures are largely absent [6]. The consequence is that national heating strategies are substantially weak and the sector, despite its importance, is left without clear targets to utilize its significant potential of energy efficiency investments and the utilization of renewable and excess heat.

Previous studies of the Heat Roadmap Europe (HRE) research initiative have indicated significant synergies between energy efficiency and the development of district heating [2]. Final heat demands could cost-effectively be reduced, while excess heat and renewable energy could see increased utilization [7]. Possible district heat supply shares of 40–70% of the heat demands in European Union (EU) member states (MS) were identified [8]. It appears that most of the heat demand could be met with renewable energies and excess heat from industry and power generation at no fuel cost, at significantly reduced greenhouse gas emissions, as well as at reduced energy import reliance and including the potential of higher employment.

The heating sector of Europe is characterised by great diversity in terms of supply technologies, building properties, settlement structures, costs, and regulations. This makes the formulation of identical and uniform national strategies irrelevant. Instead, plans for heat supply need to be based on local information. The nature of heat supply requires a local analysis of heat demand densities and the distribution of heat demands within urban and rural areas. In most countries however, there is a lack of (publically) available data on the distribution of heat demand.

Therefore, the formulation of strategies and policies requires a quantification of the potentials and costs of de-carbonizing the heating sector. Various means to achieve the latter exist, such as enhancement of end-use efficiency in buildings, the use of renewable and excess heat sources, individual heat pumps, or the establishment of collective heat supply infrastructures such as district heating (DH) and the likely use of excess heat potentials, low-enthalpy heat from renewable sources, as well as the sectoral interconnection (power to heat).

In the literature, existing research includes heat atlases, which describe current heat demands and the potentials to develop district heating. Blesl et al. [9] describe a heat atlas for Baden-Württemberg in Germany to identify model regions for heat supply. Similarly, Sächsische Energieagentur [10] has prepared an excess heat atlas for Saxony, and Geomer [11] has developed commercial software for a heat atlas for all of Germany. In the UK, national heat atlases [12] as well as atlases for London [13] and Scotland [14] have been produced. Gils et al. [15] have prepared a heat atlas specifically for the assessment of district heat potentials in the USA, while Soltero et al. [16] have built a decision support system to identify potentials for the co-generation of heat and power (CHP) in Spain. In Denmark, where heat supply planning has a long history, and where the public data infrastructure is highly developed, heat atlases have been prepared since the 1970s; recent examples are Möller et al. [17] as well as Petrovic and Karlsson [18]. Most of these heat atlases are being used for district heat expansion planning under consideration of energy efficiency and the use of renewable energy sources. Möller and Lund [19] mapped possible conversion of individual natural gas boilers to district heating supply and modelled the consequences for the Danish energy system using a heat atlas of current and potentially reduced heat demand. Sperling and Möller [20] studied the overall benefits of end-use energy savings and district heating expansion scaled-down to town level. The same heat atlas was used by Zvingilaite and Balyk [21] to model heat savings in buildings with different shares of district heating. The method of mapping was further refined by Nielsen and Möller [5]. Finally, Grundahl et al. [22] modelled district heating expansion potentials in Denmark comparing consumer versus socio-economics. Common to these heat atlases and applications is that they are mostly based on locally and regionally available data, with the exemption on Denmark, where national building registers facilitate the development of such. Still, no coherent heat atlases for the entire continent exist at the desired spatial resolution. The present research therefore ultimately aims to extend the body of knowledge with a cross-border heat atlas for all of Europe.

In the HRE research initiative, three earlier studies contributed to the development of a spatially disaggregated Pan-European Thermal Atlas (Peta). While Peta 1 was limited to the description of heat demands and possible supplies on the Nomenclature des Unités territoriales statistiques (NUTS) 3 level [6], Peta 2 already achieved a geographical resolution of 1 km^2 [7], at which supplementary analyses at small-scale statistical levels such as NUTS-3 could be carried out [23]. Peta 3, developed as part of the EU Stratego Project, partly was based on a resolution of 100 m [8]. However, its limitations lay in the confinement to urban areas alone, its restricted statistical confidence levels [24] and the lack of geographical coverage, see Table 1.

However, geographical coverage is only one aspect of the present research. Most examples of heat atlases do not go beyond mapping, leaving out the necessary technical, economic and planning information to provide the basis for developing heat supply strategies. Hence an atlas may need to calculate heat demand densities for defined area units; map coherent areas where district heating is technically possible; and identify the economic potential of district heating. In other words, such a tool must be geographically explicit and quantitative. To address this knowledge gap, the present paper presents a coherent and consistent heat atlas, based

Table 1
Overview of the main features of previous Peta versions.

Peta version	Main features	Coverage	Main disadvantages
Peta 1 (2012)	Heat demand distributed to NUTS-3 level	EU27	Impossible to know the extent of DH areas.
Peta 2 (2013)	1 km population raster to distribute all heat demands. Heat demand density statistics per MS.	EU27	Lack of resolution. Limited focus on DH. Lack of dissemination.
Peta 3 (2015)	Heat demand (residential, service) distributed to 100 m grid by means of population, land use and basic regression. Mapping of distribution investment costs, supply areas, renewable energy. MangoMaps web mapping.	Stratego countries CZ, HR, IT, RO and UK	Limited coverage. Rural areas not included.
Peta 4 (2017)	Advanced multilinear regression to model plot ratios. Coherent database to model demands, distribution costs, supply areas, allocation of excess heat, allocation of renewable energy. Advanced web mapping with ArcGIS Online.	HRE countries (14 MS)	Front end and back end largely disconnected.