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A geographic method for high resolution spatial heat planning

Steffen Nielsen*

Aalborg University, Vestre Havnepromenade 9, Aalborg, Denmark

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ABSTRACT

In many countries, DH (district heating) covers a large share of the heat market. In these countries, the best locations for DH systems have already been found. Therefore, the challenge for these countries is to find expansion potentials for existing DH. The expansion to less ideal areas requires more detailed modelling that takes the geographic placement of buildings and the differences among DH systems into account.

In the present article, a method for assessing the costs of DH expansions has been developed. The method was applied in a GIS (geographic information system) model that consists of three parts and assesses the costs of heat production, distribution, and transmission. The model was also applied to an actual case in order to show how it can be used.

The model shows many improvements in the method for the assessment of distribution costs and transmission costs. Most notable are considering distribution costs based on the geographic properties of each area and assessing transmission costs based on an iterative process that examines expansion potentials gradually. The GIS model is only applicable to a Danish context, but the method itself can be applied to other countries.

1. Introduction

Most developed countries have targets for reducing CO_2 emissions and resource consumption. The resource consumption is partly related to providing heat for buildings in the form of space heating and domestic hot water. Therefore, many countries have goals of improving buildings to reduce end-use consumption and improve efficiency by using more efficient technologies. Some countries have a highly decentralized production of heat where each building provides for itself; other countries, like Denmark, have a more centralized production in which heat is transferred to buildings through distribution networks. The latter is generally referred to as DH (district heating) systems and are used all over the world. DH has developed differently depending on planning traditions and the degree of technological advancement at the time the networks were built. These variables create significant differences in efficiency and the share of the heat market DH in each country. Fig. 1 shows the percentage share of the population that is supplied by DH in 19 countries.

Fig. 1 illustrates that many countries already have implemented large shares of DH, while others still have a significant potential for establishing new DH systems. Within dense urban areas, DH is often more feasible than individual heating, which means that in countries where DH is not yet widespread, the expansion potential can be found by examining larger cities in regard to heat densities and available resources. Examples of analyses on this level are [2–4], where the DH potential is found based on statistics of population density in European cities. However, when DH is more widespread in a country, the areas to which DH can feasibly be expanded become more difficult to see. Examining DH potentials in a region where it is already widespread requires more detailed data on where the heat demands are located within the region.

In Denmark, detailed data on buildings is available through public databases where building information is available on an address level though the Danish buildings register (BBR). The BBR is currently being updated with information on heat demand. However, a method has been developed to estimate the heat demand in buildings based on the age, type and usage of the building [5]. This method was applied in Refs. [6–9] to create a heat atlas, which includes information on a building level regarding heat demands, saving potential, current supply, and costs related to realizing the savings potential. Meanwhile, other public databases have also been improved to provide a higher level of detail in planning decisions. The public topographical maps in the FOT database [10], which includes topographic base maps with a common cartography that is used to digitalize other data, is an example of this.

* Tel.: +45 99408412.
E-mail address: steffenn@plan.aau.dk.

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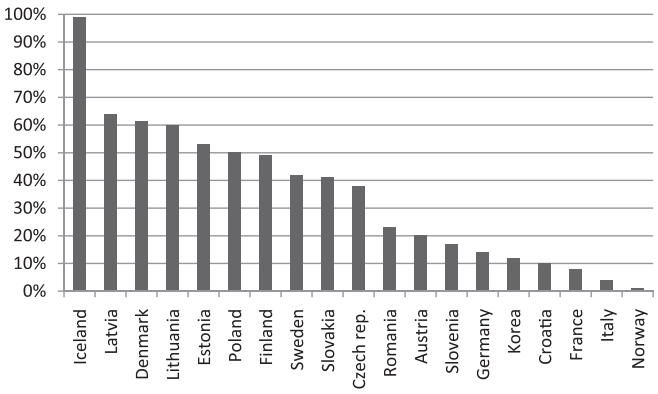

Fig. 1. Share of population served by DH [1].

The FOT database is continuously being improved to include more detail. The common planning system for municipalities is another important and rapidly improving database (PlansystemDK), which includes information on where DH and natural gas areas are located. Using this detailed data makes it possible to examine DH potentials in more detail for a country in which DH is already widespread, like Denmark. Hence, demand, supply, and planned supply can be mapped for single buildings.

In the current Danish context, there are two primary focus areas of DH research. References [11,12] are recent examples of the first focus area, which looks into transmission lines to smaller towns in low density areas. The other focus area is on developing low temperature DH [13–15] to try to minimize heat losses on the grid and improve production efficiency. In other countries, the focus areas are different; for instance, in Sheffield, in the UK, the focus is more on expanding DH and utilizing more combined heat and power [16,17]. In Sweden, the focus has been to locate wasted heat from industries to be used in DH systems [18–20]. The focus areas change over time, so even though the detailed data and methods cannot be applied to all countries today, they could be useful for these countries at a later date.

The heat atlas has already been used to examine the potentials for DH in Denmark; in 2008, it was used in Heat Plan Denmark [9]. It has been used in scientific articles as well [7,8,21,22]. These articles are based on older information regarding the municipal zoning areas where only areas with an existing collective natural gas supply are considered to have future DH potential. In a recent article [23], an updated and detailed model was created to examine the DH expansion potential in Denmark. The model included all areas outside DH, not just the areas presently supplied by collective natural gas. The article developed a new method for finding DH expansion potential, with costs being separated into costs related to transmission, distribution or production. The present article focuses on key parts of the model that required improvements. First, the model for assessing the distribution costs was based on a statistical method, which did not take the actual placement of the buildings within each area into consideration. The transmission cost model was based on a simple method, drawing single transmission lines from each possible area to the nearest DH area. A better model would take previous extensions into account, making a more continuous extension.

2. Objective

The objective of this article is to further develop the geographic methods for heat supply planning based on public data registers. There are two main areas of focus:

1. How can the capital cost and heat losses of distribution within new areas be assessed, taking into account the geographic placement of buildings within an area?
2. How can the capital cost of transmission lines be assessed so that it includes expansion potential based on previous extensions, taking existing production capacity into consideration?

All costs in the article are based on socioeconomic costs. These include investment costs both in production technologies and DH pipes. Fuel costs are based on market prices and include transportation and handling. Operation and maintenance costs include salaries and building-related costs. However, the socioeconomic costs do not include taxes, VAT (value added tax), and other politically-decided costs, which are usually included in private and business economic calculations. These externalities were all taken into account in the application of the geographic model to a concrete case in order to demonstrate its applicability and test its performance. The potential for connecting buildings within existing DH areas and the potential for establishing completely new DH areas are not included in the model presented in this article. Here, the focus has solely been on expansion of existing DH areas due to Denmark's already expansive DH system being more conducive to growth than creation. In countries with a lower coverage of DH, the potential for establishing new DH areas would be greater.

3. Data sources

GIS (geographic information system) analyses depend heavily on the quality of the data source available; better sources allow for much more detailed analyses. In Denmark, there is a thorough public registration on housing data and energy production data, which is covered in this section along with the other data sources used.

3.1. The heat atlas

The heat atlas of Denmark has been under development for several years and was used by Refs. [6,8,21], among others. The heat atlas is a geographic database of all approximately 2.5 million buildings in Denmark. The database includes information on current heat supply and annual heat consumption, as well as scenarios for heat reduction potentials and their associated implementation costs. The information on heat consumption and reduction potentials is based on a model from the Danish Building Research Institute (SBi) [5] that estimates building consumption based on age, type, usage and area. This information is available in the BBR (The Danish Building Register), to which the SBi method has been applied to create the heat atlas of all buildings in Denmark. It is quite unique to have this information for all buildings. Nonetheless, examples of the creation of other heat atlases which are based on other sources [24,25] shows that it is usually possible to find a way to estimate heat demands and create a local heat atlas.

3.2. The topographical base maps

The topographical base maps used in this article are from the FOT (Fælles Objekt Typer) database maintained by FOTdanmark [10,26], an association initiated in 2007 as part of a partnership between the Danish National Survey Cadaster and the larger Danish municipalities. Since then, the collaboration has expanded to include most municipalities in the country. The idea behind the project was to create a geographic database with a coherent and uniform dataset that makes it easier to exchange information from the local to the national level. It is also useful for researchers since it covers the whole country and is updated on a regular basis. FOT is the Danish implementation of the EU INSPIRE directive [27], which