International Gas Union Research Conference 2014 – WP5-7

Methodology for GIS-based heat demand analysis in large urban areas

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ABSTRACT

In this study GIS-based (GIS - geographic information system) analysis are described, which consider the location heat demand (households, commercial, industry etc.). Based on a database with more than 20 million data sets a wide variety of heat analyses can be done. The evaluation of individual heat consumers and the generation of heat maps show areas with a high or low heat demand. Other factors give information about ways to set up a central heating plant and the development of a heating network. Considering different scenarios allows on one side economic evaluation of heating networks and on the other hand a future forecast of the heat demand can be done. All results help to perform cost-effective project planning and to identify economically viable locations.

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1 INTRODUCTION

In Germany the heat consumers can be divided into the main categories of industry, business, municipalities and households. While households and commercial especially need room heating and hot water, the industrial sector mostly requires process heat at higher temperature level. Overall, the total German heat demand per year is approximately 5,000 PJ [2]. This demand is distributed all over Germany.

Currently the heat supply is in a transitional phase. Natural gas, oil and coal have dominated the last decades. In recent years a trend towards alternative heating devices, such as heat pumps and regenerative energies can be observed. Simultaneously the heat demand decreases due to building redevelopments and efficiency improvements. Demographic trends also affect the heat demand significantly. By 2050, the process heat demand in Germany will reduce to 30 % and the room heating requirements by up to 60 % [3].

The development of the heat demand depends on several factors, which also show regional differences. The regional conditions are of high importance for the development of new and the optimization of existing infrastructures. The analysis developed by DBI - Gastechnologisches Institut gGmbH Freiberg provide individual heat consumers and buildings and in detail their combination (supply areas). Mostly the market area of utilization companies are so huge, that detailed local information are missing. GIS allows the combination of heat demand data with geographic information for large areas. So different thematically data can be connected with quantitative statements, e.g. heat demand. In result forecasts about the future economic energy supply can be made.

2 DATABASE

A comprehensive database of categorized heat consumers is the basis of all analyses. Therefore in the DBI-database up to 20 million building information with individual attributes are available. In addition for more than 500,000 data sets in over 100 categories exist specific consumer (industry, business and municipalities) information. Every data set has an individual specific heat demand, which is divided into room heating, hot water and process heat. In result every location has an individual heat demand based on specific attributes. Furthermore, the annual heat demand can be transformed into specific annual heat profiles.

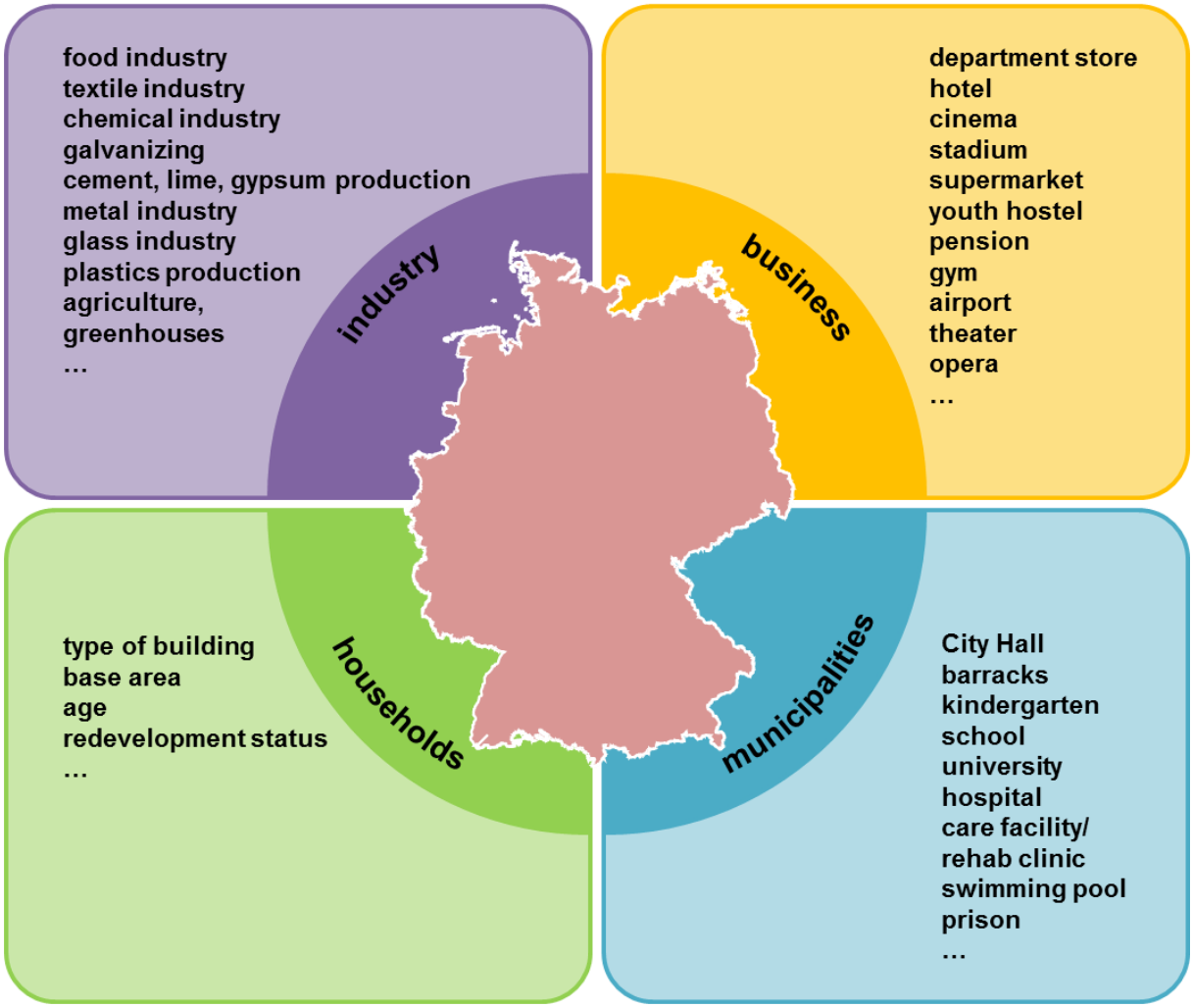


Figure 1: Categorized heat consumers (selection) [4]

3 METHODOLOGY

The heat demand database is used for different analyses. These include the evaluation of the heat demand for each customer and also the optimization of heat-supply infrastructure of large urban and industrial areas. The various data sets have to be combined sensible to avoid wrong results and duplicates.

The categorization of the heat consumers helps to reflect the structure of villages and towns. For example business and industrial areas are detected (Figure 2). Considering the exact location analysis statements about every heat customer in a large area can be made. So the evaluation of the private, business, municipal and industrial heat consumers enables a unique identification of the economically interesting locations.

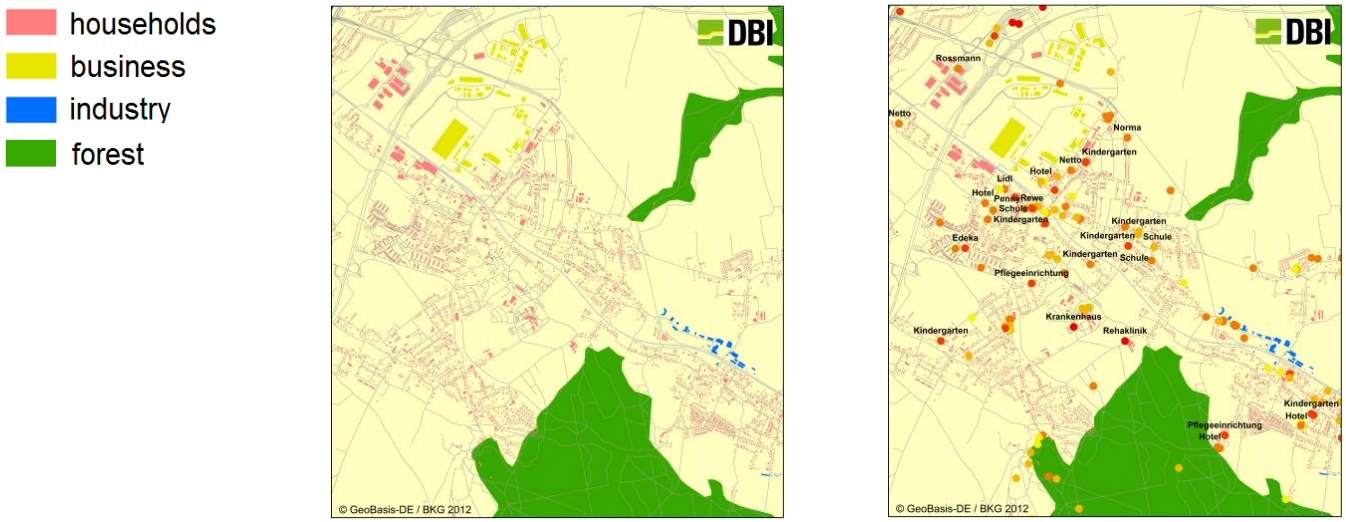


Figure 2: Categorization and identification of heat consumers (left: general classification, right: classification, including more location information) [4]

The combination of all individual heat consumers leads to maps, which show areas of high and low heat demand. So large areas can be evaluated. In result heat potential maps are created. Afterwards the economically interesting areas can be identified easily.

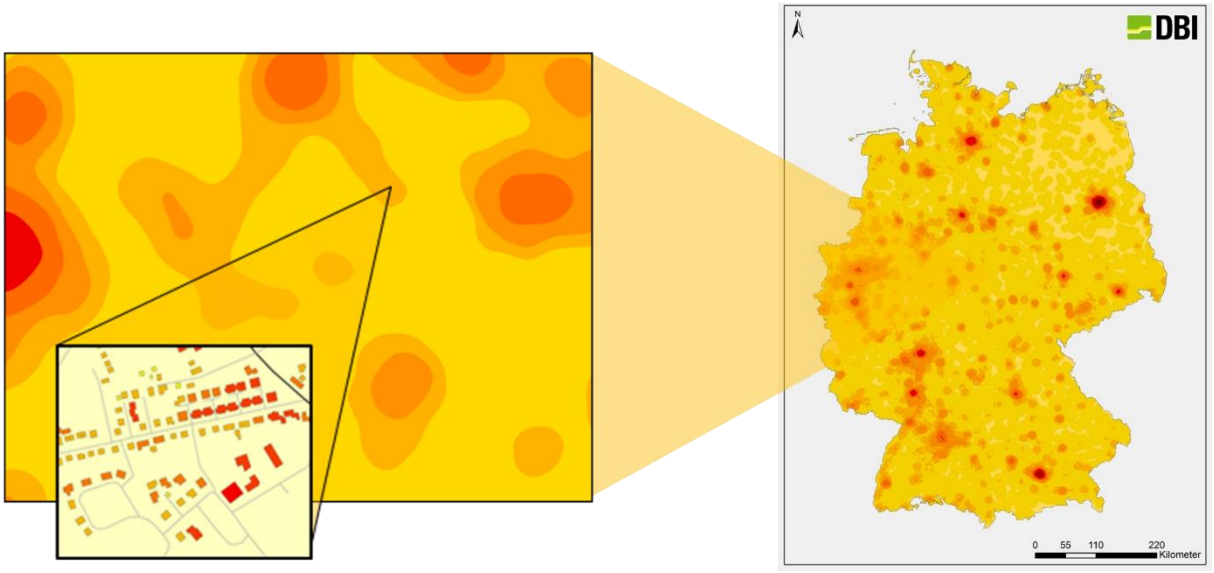


Figure 3: Potential heat map based on a large number of local data [4]

Often the current situation of heat supply is of interest. Based on the natural gas grid the differentiation between natural gas supplied customers and the other ones is possible. So in a further step the identified non-natural gas supplied customers are analyzed in detail. Industry, business, municipalities and households are evaluated by their heat demand, structure and location. Thereby the single location is considered, so that the economically important heat consumers can be identified. The result is a ranking of the most important heat customers. This ranking also includes further information about the heat customer, such as address, category, annual heat demand, etc. Thus, the contact to buildings owners is very user friendly. Furthermore informative and illustrated maps and reports can be created.

Also heat demand forecasts can be done. Therefor additional information are needed:

- demographic trend
- building redevelopment
- efficiency improvements

Demographic trends affect the heat demand significantly. Figure 4 shows the development of heat demand for different buildings by the year 2040. Mostly industrial buildings have a lower decrease than residential ones. Especially for planning new heating networks and evaluation existing ones these analysis are important.

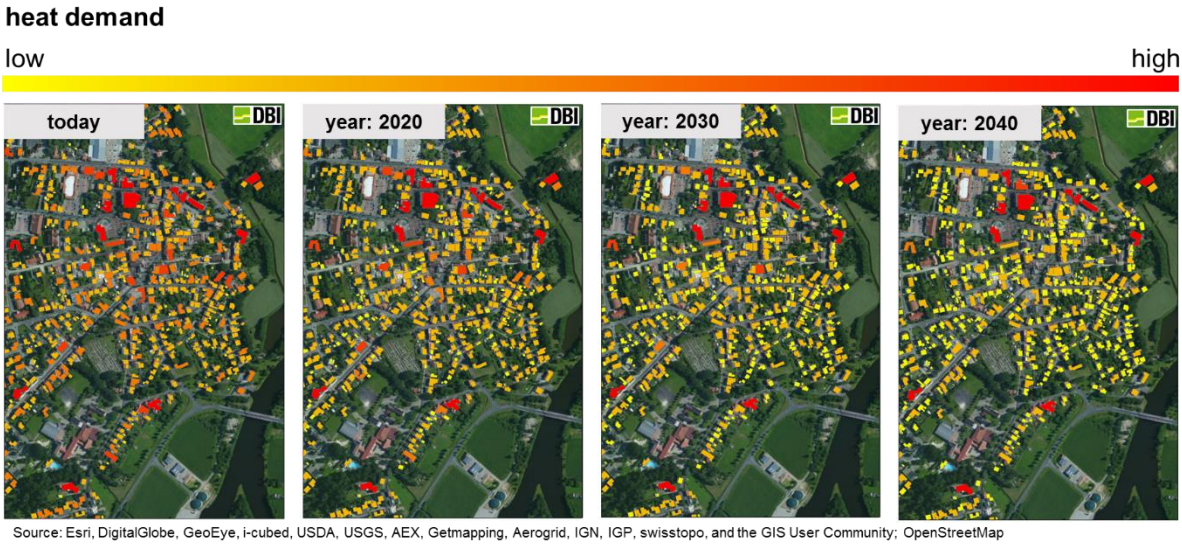


Figure 4: Development of the annual heat demand by 2040 [5]

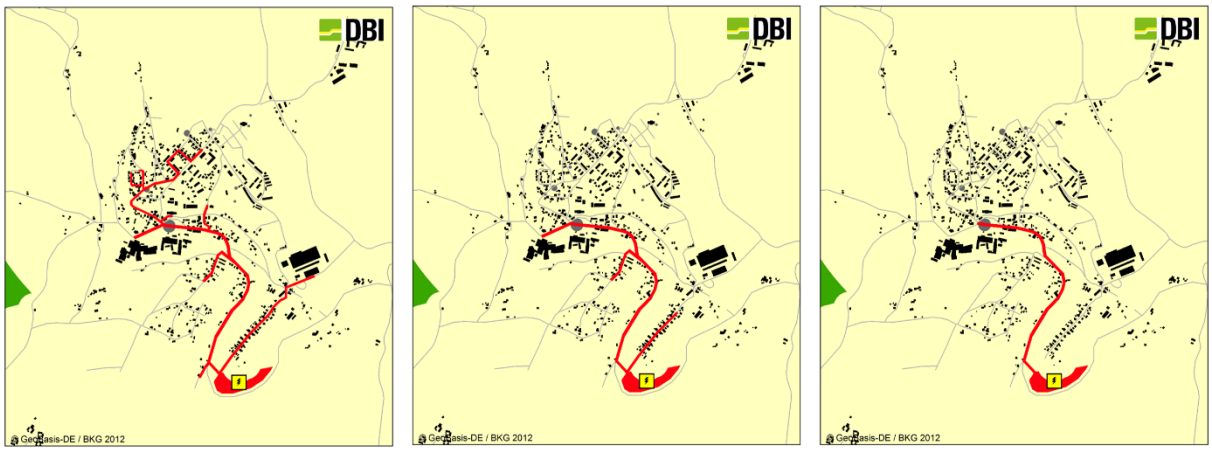
In result new supply infrastructure could be planned and analyzed with the help of these heat maps. The heat consumers are connected by a heating network. For a quantitative evaluation of the consumers and particular supply areas some variables have to be defined. The economic analysis considers the following factors:

- heat demand
- distances
- heat occupancy

Considering the heat demand the system boundary is to differ. Therefor buildings and other heat consumers are summarized for each street, so that streets or street sections build a supply area. In the same way the heat demand can be summarized. The modeling of a heating network represent the supply area but also a central heating plant. The central heating plant, such as CHP or a storage tank, can operate with natural gas, oil, biogas, biomass, LPG etc. The economic evaluation of a long term profitably heating network depends on the heat demand and the heat occupancy. The closer the consumers are together, the greater the heat occupancy for the same heat demand. The following equation describes the relationship between heat demand and grid length.

$$q_i(t) = \frac{\sum_{i=1}^{i=n} Q_i\,(t)}{\sum_{i=1}^{i=n} l_i + l_{main}} \qquad (1)$$

Based on heat occupancy different scenarios can be calculated. With increasing heat occupancy the number of detected supply areas decreases (Figure 5). In result the best economical locations are identified. Also the increasing heat occupancies detect the center of the heating network.



1.000 kWh/m 4.000 kWh/m 10.000 kWh/m

Figure 5: Potential supply area (red) and potential central heating plant ( ) for different minimum heat occupancies [4]

Based on the GIS-datasets the results can be shown in maps. Furthermore all data can be exported from GIS in another format like excel-tables. Thereby further individual calculations and analysis are possible. The compiled information makes the project acquisition easy. In result a ranking of the best locations for central heating plants is available.

Table 1: Ranking of potential heating networks [4]

Ranking	town/ street	required heat quantity in kWh/a	grid length in m	heat occupancy in kWh/m
1	XXXXXXXXX	18.956.200	3.625	5.229
2	XXXXXXXXX	17.124.500	3.701	4.627
3	XXXXXXXXX	16.850.300	3.703	4.550
…	…	…	…	…

4 CONCLUSIONS

The demographic and technological change affects the heat supply of industry, business, municipalities and households. Thereby the development is influenced by many individual factors. So general statements cannot be made. Especially large areas the data for heat demand is mostly unknown. The exact location knowledge is essential for more detailed information about the current and future supply structure.

GIS is quite suitable to analyze the heat demand for small and large areas. An extensive database is the basis for such complex analysis. A categorization of the heat consumers ensures a differentiation of structure and reflects the different heat demands. The evaluation of each heat consumer enables the representation of realistic and accurate results. Based on heat maps new costumers can be detected and the infrastructure of heat supply can be evaluated as well as optimized.

For further processing the user has the advantage of simplified decision. Especially in large supply areas the detection of new customers and also the assessment of the existing supply system is difficult. The results of GIS analyses helps to identify economically interesting energy supply options and acquire new customers. The individual attributes of each heat customers forms the basis of further project management. Furthermore the heat maps and the database are an effective working tool for the further project development and implementation.

5 Symbols and Abbreviations

l	length in m
q	heat occupancy in kWh/(a*m)
Q	heat demand in kWh/a
t	time in h
i	customer (building or street)
n	number of customers
main	main line of the grid (connection between CHP and heating network)

6 List of References

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7 LIST OF FIGURES

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