HEAT DEMAND ESTIMATION

Annex to D.T2.2. Planning Guidelines for Small District Heating

Version 1

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Content

1. Introduction

This document summarizes some relevant data sources (tools, databases) and simple methods on the estimation of yearly heat demands of buildings. It gives a short description on GIS tools and which data can be easily retrieved (see chapter 1.1), presents a data base on values of the yearly heat demand that are mainly based on building typologies and the year of construction (see chapter 1.2), simple calculation methods based on Heating Degree Day (HDD) measurements (see chapter 1.3) and a summary on proposed values for the heat demand for domestic hot water from different data sources (see chapter 1.4).

1.1. Heat demand estimation using existing free-available GIS-tools

Pan-European Thermal Atlas 4 (Peta4)

The Pan-European Thermal Atlas 4 is an online map carried out within the Heat Roadmap Europe 4 (HRE4) which main aim is the mapping of relevant information for the heat and cold market ('Pan-European Thermal Atlas 4.3', n.d.). It includes information about heating and cooling demands as well as potential of excess and renewable heat sources for 14 European countries, among them Italy, Poland, Germany and Austria. A broad description regarding the methodology, assumptions, data, and tools used is given in (Persson, Möller, & Wiechers, 2015).

Heating demand densities are available by hectare grid resolution. Specific values of the cell values cannot be read, results are presented in four intervals, specifically: < 50 TJ/km^2, 50 – 120 TJ/km^2, 120 – 300 TJ/km^2 and > 300 TJ/km^2. Notice that 1 TJ/km^2 are approximately 0,2778 kWh/m^2. A summary of the key features, briefly description of the information available in PETA4 and example of its potential applicability, i.e. use cases, can be found in (Persson, Möller, Wiechers, & Rothballer, 2015).

THERMOS

THERMOS is a free open-source software that aims at offering local authorities address-level data for the optimal design of new or expansions of district heating systems. Though the main application is the predesign of the district heating system and not the estimation of the heat demand, the software includes data regarding the heat demand at a building level which can be used to identify high density areas. The heat demand data is based on some/all the following information: three-dimensional building shape/size, internal building temperatures and outdoor air temperature, building thermal efficiency and other benchmark models (e.g. water heating demand). More detailed information can be found in (*Accelerating the development of low-carbon heating & cooling networks. Capacity Building and Train-the-trainer programme Module 2: Energy System Mapping and Modelling with THERMOS*, n.d.).

It is important to mention, that the main use of the tool is to assist in the design of an optimal district heating system. For that purpose, the heating demand values at a building level can be overwritten with more detailed data, when available. Based on the defined ecological, economic and technical boundary conditions the tool can calculate an optimal district heating system for the selected area.

Hotmaps

The Hotmaps project started in October 2016 and will last for four years ('Hotmaps project', n.d.). The main goal of the Hotmaps project is the development of an open source heating/cooling mapping and planning toolbox and to provide default data for EU28 at national and local level. The Hotmaps toolbox is already available and contains data at different scales resolution, being 1 hectare the finest grid element and national the coarsest ('Hotmaps toolbox', n.d.). A useful option of the tool is the possibility to select specific areas (e.g. hectare cells or regions) and obtain a results summary for the selection (e.g. yearly heat demand, heat densities).

1.2. Estimation of the yearly heat demand based on the building category

The heat demand for a building stock can be estimated based on often free available information (e.g. in the land registry), such as building construction age and building typology. In this regard, there are two relevant EU projects, TABULA and its follow-up project EPISCOPE, from which values for the specific heat consumption of different building classes can be obtained ('IEE Project EPISCOPE', n.d.; 'IEE Project TABULA', n.d.). During these projects residential building typologies have been developed for 13 European countries. Each national typology consists of a classification scheme grouping buildings according to their size, age and further parameters and a set of exemplary buildings representing the building types. Following the seasonal method described in EN ISO 13790 the energy need for space heating and domestic hot water preparation has been calculated for each of this building typologies, see (Loga & Diefenach, 2013) for more information about the applied methods. Due to the lack of information about the real utilisation conditions and exact thermal properties of existing buildings deviations between the obtained results with the model and measured consumption can be expected. Because of this uncertainty, the obtained results are complemented with a second type of calculation, it mainly consists in the application of an empirical adaption factor to the obtained results. Nevertheless, the TABULA project can serve together with the information of the land registry to characterise the energy consumption of specific area. Values for the specific heat demand can be obtained directly from the webtool or using the excel workbook "TABULA.xls" (freely available on demand). An exemplary subset of results from the tool is shown in Table 1. Heat demand for domestic hot water (DHW) is not included in the Table 1.

Table 1: Subset of result regarding specific heat demand for heating purposes in kWh/(a.m^2) from ('TABULA WebTool', n.d.) for different building classes and construction year periods for Slovenia. Results from the adapted calculation ("expected measured consumption") for non-renovated buildings. Data Retrieved in July 2019.

Construction year	Building type			
	Single family house (SFH)	Terraced house (TH)	Multi Family House (MFH)	Apartment Block (AB)
… 1945	245,1	91,4	122,4	140,6
1945 … 1970	117,9	100,8	105,5	141,8
1970 … 1980	93,7	86,4	112,6	117
1981 … 2001	92	75,1	100,6	101
2001 … 2008	58,9	74,5	78,2	48,3
2009 …	77	72,7	52,2	57,1

1.3. Estimation of the yearly heat demand using the Heating Degree Day (HDD) measurements

Measurements of the heating degree days can be used to estimate the yearly heat demand by means of very simple methods. This chapter includes a short description of the definition of HDD and two simple methods to estimate the yearly heat demand.

Heating Degree Day (HDD) definition

The HDD assumes that if the daily average outdoor air temperature falls below a certain threshold value T_{th} (to be defined), a heating demand arises.

The HDD is usually calculated as the sum of the difference between the daily average outdoor air temperature, T_m^i and a reference temperature T_{ref}, see Equation 1 and Equation 2. The daily average can be calculated from the hourly temperatures. Further methods to calculate Degree Days (DD) can be found in (Mourshed, 2012).

$HDD = \sum_{i=1}^{n=365} \Delta T^i$	**Equation 1**
$\Delta T^i = \begin{cases} T_{ref} - T_m^i & for \;\; T_m^i \leq T_{th} \\ 0 & for \;\; T_m^i > T_{th} \end{cases}$	**Equation 2**

The HDD can be calculated using local weather data and setting the reference and threshold temperature. For a first approximation the HDD values from ('Eurostat database', n.d.) can be used. Monthly and yearly values of the HDD have been calculated using $T_{ref} = 18$ °C and $T_{th} = 15$ °C at national level and as well as for local regions as defined in ('COMMISSION REGULATION (EC) No 105/2007', 2007). A subset of yearly and monthly HDD values for several target countries of the ENTRAIN project are summarized in Table und Table .

Table 2: Yearly HDD of several EU countries for different years and averages. Data retrieved from ('Eurostat database', n.d.). HDD Calculated for $T_{ref} = 18$ °C and $T_{th} = 15$ °C.

Country		Year										Average 2009 - 2018
Code	Name	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	
AT	Austria	3.196	3.503	3.419	3.322	3.125	3.640	3.547	3.394	3.907	3.511	3.456
DE	Germany	2.776	2.964	3.005	2.909	2.661	3.288	3.130	2.872	3.630	3.081	3.032
HR	Croatia	2.148	2.331	2.273	2.250	1.894	2.301	2.364	2.370	2.529	2.279	2.274
IT	Italy	1.754	1.878	1.762	1.810	1.635	1.940	1.954	1.864	2.070	1.942	1.861
PL	Poland	3.125	3.290	3.286	3.113	3.095	3.504	3.550	3.315	3.920	3.449	3.365
SI	Slovenia	2.584	2.833	2.757	2.700	2.342	2.867	2.833	2.821	3.135	2.779	2.765

Table 3: Monthly HDD of several EU countries for 2018. Data retrieved from ('Eurostat database', n.d.). HDD Calculated for $T_{ref} = 18$ °C and $T_{th} = 15$ °C.

Country		Month											
Code	Name	Dec	Nov	Oct	Sep	Aug	Jul	Jun	May	Apr	Mar	Feb	Jan
AT	Austria	543	392	219	88	24	20	47	88	164	504	593	515
DE	Germany	433	371	200	73	11	3	22	63	150	470	543	435
HR	Croatia	447	264	96	38	2	0	6	12	70	376	465	371
IT	Italy	344	188	57	16	5	4	10	39	97	298	371	325
PL	Poland	513	400	225	71	6	10	29	53	144	548	594	531
SI	Slovenia	506	316	147	51	7	0	6	27	106	443	530	444

Calculation of heat demand using the HDD

As the HDD are known, the heating demand in MWh/a can be calculated with two different approaches, “Use of overall heat loss coefficient UA” and “Extrapolation of the heat demand”. In both approaches the heating demand is assumed to be proportional to the HDD.

Use of overall heat loss coefficient UA

As described in (Kalogirou, 2014) the heating demand in MWh/a can be obtained with Equation 3. The overall heat loss coefficient UA in W/K mainly represents the air infiltration and heat transmission losses through the building envelope. It should be noted that the method does not include internal heat gains and dynamic characteristics of building, i.e. heat capacities are disregarded.

$$Heating\ demand = \frac{86.400}{2,\hat{7}e^{10}} \cdot UA \cdot HDD$$	**Equation 3**

The UA value need to be defined. It can be estimated based on the construction data, done after knowing the envelope geometry and construction materials, or derived from the installed heating capacity Q_{inst}. In this regard, it can be assumed that the heating system have been sized for specific indoor and outdoor air temperatures according to Equation 4.

$$UA = \frac{Q_{inst}}{(T_{indoor} - T_{outdoor})}$$	**Equation 4**

Extrapolation of the heat demand

HDD can be used to normalize the heat consumption of a building as shown in Equation 5.

$$Heating\ demand_{normalized} = \frac{Heating\ demand}{HDD}$$	**Equation 5**

The normalized heat consumption as defined in Equation 5 is usually used to fairly compare the heat consumption between buildings in different regions or years. Nevertheless, the normalized heat demand can be also used with help of Equation 6 to extrapolate the heat demand of the chosen building (or group of buildings) to another climate, i.e another location. Thus, the known heat demand of similar buildings of other regions can be normalized and extrapolated to the new location. This method can be useful when no information regarding the heat consumption of the buildings in the region is available.

$$Heating\ demand_{new\ location} = HDD_{new\ location} \cdot Heating\ demand_{normalized}$$	**Equation 6**

1.4. Estimation of the heat demand for domestic hot water (DHW)

Based on over 2 Mio. accounting measured data, online-questionnaires, literature research and data from a specialized software co2online the heat demand for hot water preparation could be accurately estimated in the project “Nutzenergiebedarf für Warmwasser in Wohngebäuden” (Offermann et al., 2017). Based on data from the Techem and Brunata companies, hot water energy demand per useful area is between 9 and 13 kWh/(a.m^2) for multi family houses. Based on data from the company ista, the average for water demand is 11,1 kWh/(a.m^2) and 10 kWh/(a.m^2) specifically for multi family houses. Based on 331 data sets for single family houses collected by means of an online survey, the average of heat demand for DHW was calculated to 9,2 kWh/(a.m^2).

Based on the mean values from the data analysed, (Offermann et al., 2017) proposes to use Equation 7 to estimate the heat demand for domestic hot water per useful floor area E_{DHW} in kWh/(a.m^2). Where $\tilde{A}$, is the median of useful floor area of living units of the buildings.

$$E_{DHW} = \left(15 - \left(\tilde{A} \cdot 0{,}04\right)\right) \quad \textbf{Equation 7}$$

A minimum limit for the heat demand for domestic how water is set to 7 kWh/(a.m^2). Thus the obtained values with Equation 7 are between 7 and 15 kWh/(a.m^2). Similar to the ones used in ('TABULA WebTool', n.d.), 10 kWh/a.m^2 for single family houses and terraced houses and 15 kWh/(a.m^2) for multi family houses and apartment blocks, but lower than 20 kWh/(a.m^2), the value suggested in (Good et al., 2008).

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