2050

Heat Roadmap Europe

A low-carbon heating and cooling strategy

Updated Peta atlas for each MS with the final level of district heating recommended in WP6

Deliverable 6.5

Project Number:	695989
Project acronym:	HRE
Project title:	Heat Roadmap Europe: Building the knowledge, skills, and capacity required to enable new policies and encourage new investments in the heating and cooling sector.
Contract type:	H2020-EE-2015-3-MarketUptake

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 695989.

Deliverable number:	D6.5
Deliverable title:	Updated Peta atlas for each MS with the final level of district heating recommended in WP6
Work package:	WP6
Due date of deliverable:	31 August 2018
Actual submission date:	M30 - 31/08/2018
Start date of project:	01/03/2016
Duration:	36 months
Author(s)/editor(s):	Bernd Möller (EUF), Urban Persson (HU)
Reviewer(s):	Brian Vad Mathiesen (AAU)
Project Coordinator	Brian Vad Mathiesen, Aalborg University

Dissemination Level of this Deliverable:	PU
Public	*PU*
Confidential, only for members of the consortium (including the Commission Services)	*C0*

Contact: Bernd Möller
E-mail: Bernd.Moeller@uni-flensburg.de
Centre for Sustainable Energy Systems
Europa-Universität Flensburg (EUF)
Auf dem Campus 1
24943 Flensburg
Germany

E-mail: info@heatroadmap.eu
Heat Roadmap Europe website: www.heatroadmap.eu

Deliverable No. D 6.5: Other, Public.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 695989. The sole responsibility for the content of this document lies with the authors. It does not necessarily reflect the opinion of the funding authorities. The funding authorities are not responsible for any use that may be made of the information contained therein.

Table of Contents

1. Introduction

In Europe, there is a clear long-term objective to decarbonise the energy system, but it remains largely unclear how this could be achieved in the heating and cooling sector. The Heat Roadmap Europe (HRE) project will enable new policies and prepare the ground for new investments by creating more certainty regarding the changes that are required. Heat Roadmap Europe is co-funded by the European Union, brings together 24 academic, industrial, governmental and civil society partners, and runs from 2016 to 2019.

The overall objective of the HRE project is to provide new capacity and skills for lead users in heating and cooling sectors, including policymakers, industry, and researchers at local, national, and EU levels, by developing data, tools, and methodologies necessary to quantify the impact of implementing more energy efficiency measures on both the demand and supply sides of the sector. The geographical scope of the project covers the 14 EU28 member states that in 2015 accounted for largest volumes of heat demands in residential and service sector buildings. These countries are: Austria, Belgium, the Czech Republic, Finland, France, Germany, Hungary, Italy, the Netherlands, Poland, Romania, Spain, Sweden, and the United Kingdom.

1.1. Deliverable objective

The objective of this deliverable is to report on provided input data to work package 6 (WP6), Task 6.4, for the assessment of recommended levels of district heating (DH) in each of the 14 member states. This input data has been rendered in work package 2 (WP2) and consists of three main parameters: a high-resolution model of the heat demand and its density; the specific investment costs for district heating systems; and the allocated volumes of industrial and energy sector excess heat for current and prospective district heating areas. All of these parameters represent spatially derived information that is used together with additional information in the energy systems modelling of WP6 to create national heating and cooling scenarios for the 14 member states.

1.2. Pan-European Thermal Atlas

The terminology Pan-European Thermal Atlas (abbreviated Peta) was first used in the HRE pre-studies in 2012 (Peta 1) (Connolly et al., 2012) and 2013 (Peta 2) (Connolly et al., 2013). A third generation of the atlas (Peta 3) was developed in the IEE project Stratego during 2014 to 2016 (Stratego, 2014). The Pan-European Thermal Atlas in this project is thus referred to as Peta 4 (Möller et al., 2018), since it constitutes the fourth iteration by which local conditions for efficient heating and cooling supply structures are comprehensively mapped with reference to the EU28 context.

The work to assemble, manage, and analyse local conditions data in WP2 of this project has been performed by use of geodatabases. In this sense, the fourth version of the Pan-European Thermal Atlas is a consistent set of geodatabases from which several different output formats are feasible. One such output format are regular data sheets, such as tables and matrices, arranged in suitable formats (MS Excel, MS Access etc.). Another format is data presentation by geographical visualisation, alternatively in the design of static maps (images) or as dynamic maps (web map layers) using the project ArcGIS Online mapping platform.

The present deliverable comprises an update of the data content in Peta 4. As the content of Peta continuously is developed as the HRE project proceeds, the geodatabases and online platform layers will represent the state of knowledge in the project. An update may hence imply extraction of new output data from the geodatabases, as well as generation of new geographical outputs, be they of static or dynamic nature. As a convention, an update of Peta 4 is indicated by a version number.

Hereby, In terms of regular data sheets, intra-project communication and sharing of geodatabase information is and has been a continuous activity within the project, where, in this context, it refers specifically to data matrices supplied by WP2 to WP6. In terms of geographical visualisation, a first version, Peta 4.1, was made publicly available in the form of dynamic map layers at the project online web map application in March 2017. A second version, Peta 4.2, opened in September 2017, and a coming third version, Peta 4.3, is planned for public launch in November 2018. The main content and characteristics of the three Peta 4 versions are outlined in the following sub-sections.

1.2.1. Peta 4.1

The first version of Peta 4 introduced three dynamic map layers, which all constituted early project results from WP2. These layers were:

- Heat demand densities
- Current district heating areas
- Excess heat activities

Peta 4.1 therefore included the basic knowledge and data from which the next iterations of the atlas could be developed. Especially the heat demand densities were of special importance since they constitute key input data for the succeeding calculations of e.g. investment costs for district heating. The 100m resolution grids of the modelled heat demands across Europe were also the first of its kind, since previous efforts had been rendered at the square kilometre level, and, as such, it represents a chief achievement in the project. For further references, see (Möller et al., 2018; Persson et al., 2017a; Persson et al., 2017b). Subsequently other EU projects have continued the development of similar heat atlases, e.g. the EU Hotmaps project (Hotmaps, 2018).

1.2.2. Peta 4.2

By the time of updating to the second version, Peta 4.2 (Peta_4.2, 2017), which maintained all layers from Peta 4.1, the activities in WP2 had produced dynamic layers also for cold demand densities, three renewable heat resources, investment costs for district heating, and for prospective district heating areas. In all, the second version introduced seven additional layers:

- Cold demand densities
- Heat synergy regions
- Biomass resources
- Geothermal heat resources
- Solar thermal district heating
- Prospective district heating areas
- Investment costs for district heating

For the renewable heat resources, input data from other EU projects were incorporated into the geodatabases. In terms of biomass resources, the BioBoost project shared data on sustainable levels of available biomass at regional levels (Pudelko et al., 2013). For geothermal heat resources, original data from the GeoDH project was used (Dumas and Bartosik, 2014), while for the solar thermal district heating potential, a collaboration with the IEA SHC Task 52 project rendered the assessments (Trier et al., 2018).

In response to the submission date of this deliverable (August 31, 2018), one additional dynamic layer, later to formally be part of the third update (see next sub-section), has been added to the Peta 4.2 list as of this date:

- Recommended DH levels

This layer is the geographical counterpart to the matrix data on recommended district heating levels that WP2 has supplied to WP6 during the spring of 2018. The layer constitute local representations, by individual prospective district hearting areas, of economic potential as a function of access to available excess heat and renewable energy sources. It should be noted, however, that actual levels of district heating to be recommended at national levels take into consideration also operational aspects and long-term development dimensions of future energy systems, why conclusive national recommendations are outputs from WP6. For further details on the additional dynamic layer, see sub-section 2.3 below.

1.2.3. Peta 4.3

By project consortia decision on 2018-08-24, the release of the third update will take place as a public launch event at the 4th International Conference on Smart Energy Systems and 4th Generation District Heating conference (SES4GDH) in Aalborg, Denmark, on November 13, 2018. On this date, the following seven additional layers are planned as additions to the previous ones:

- Recommended DH levels (update)
- Cold demand densities (update)
- Solar thermal district heating (update)
- Excess heat: Metro stations (ReUseHeat)
- Excess heat: Urban waste water treatment plants (ReUseHeat)
- Excess heat: Data centres (ReUseHeat)
- Excess heat: Service sector buildings (ReUseHeat)

As this is work currently in progress, it should be noted that minor, however not substantial, alterations to this list of contents may occur. With regard to the four new excess heat layers, these consist of the dynamic layer outputs from the on-going ReUseHeat project (ReUseHeat, 2018). In addition, cosmetic improvements to the web map application i.e. increased user friendliness, re-labelling of certain layers, additional tune-ups etc., are also planned to be part of this update.

2. Updated Peta Atlas input data to WP6

Data for the heat demand, structural investments (sub-section 2.1), and potential supplies (sub-section 2.2) has been modelled by means of extensive spatial analysis on the local level of prospective heat supply areas. For 52,112 individual areas it can be assessed whether district heating is feasible, and at which level (sub-section 2.3). The gross supply including district heating grid losses has been modelled, and demand has been split into baseload and seasonal heat demands based on climatic data. Finally, excess heat has been allocated in space and time to meet local heat demands. For ease of processing in WP6, all these data were split into progressive shares of district heating at percentages 10, 20, 30…100%. General IDs for HRE4 member countries, EU member states, and NUTS3 districts were added in order to be able to aggregate data.

In WP6, energy system analyses is carried out at national scale. This necessitates the aggregation of individual, local heat demand, infrastructure and supply data to member state level. However, the important geospatial information on the local constraints of heat supply modelling were kept intact so that the authors feel confident to say that this data set comprises the first ever coherent database on local heat supply strategies for most of the EU.

Recommendations on the level of district heating that has the highest value not only seen from the short-term and local perspective, but for the long term, smart energy systems point of view, require a thorough analysis of the contributions of each local area to achieving the aim of decarbonising the heating sector. It has been proven to be of high importance to include the local constraints that lie in the consumption, distribution, transmission, and generation of heat. The recommendation on district heating levels therefore is a combination of the data presented on the Peta 4.2 online mapping system, and the outcome of the energy systems analyses carried out in WP6.

2.1. Investment costs for district heating

As a first basis for the assessment of recommended levels of district heating in WP6, the specific investment costs for district heating systems (e.g. the distribution networks), were established on the 100m resolution grid. For the establishment of this parameter, the corresponding 100m resolution grid on heat demand densities in residential and service sector buildings was used together with construction cost data and other related parameters. The full account on these calculations are reported in (Persson et al., 2017a).

In terms of dynamic map layers, an excerpt of which is presented for the city of Berlin in Figure 1, all hectare grid cells among the 14 member states with a current (2015) heat demand above zero has been attributed a specific investment cost for district heating. The cost itself is rendered first as marginal capital distribution costs (€/GJ), indicating the cost level for new installations and expansions of current systems.

Second, by summing the accumulated investment costs and corresponding accumulated heat demand volume at this cost level, the average capital distribution cost is established.

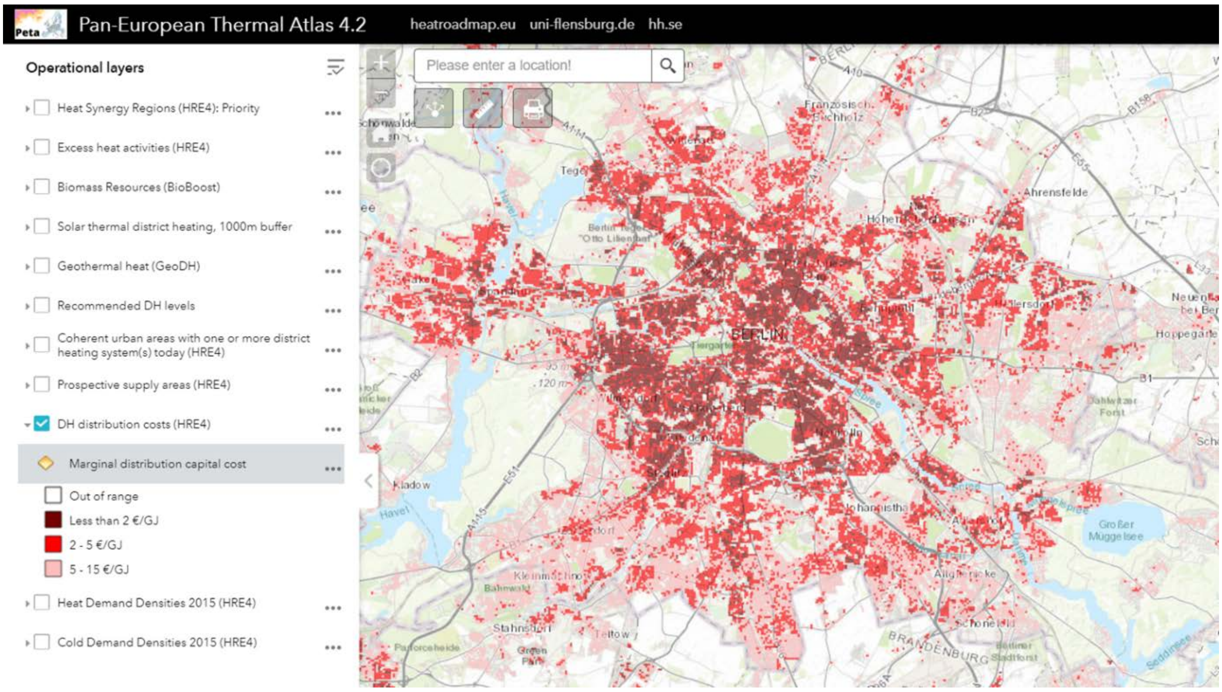

Figure 1. Excerpt from Peta 4.2: District heating distribution cost by hecatre grid cells for the city of Berlin (DE).

In terms of geodatabase data provided to WP6, heat demand volumes, as shares of total national residential and service-sector heat markets, by each respective investment cost level, are cumulated to produce national cost curves, as in Figure 2. Hereby, national modelling on recommend levels for district heating, by specific investment cost, may be performed based on locally derived, that is bottom-up, data.

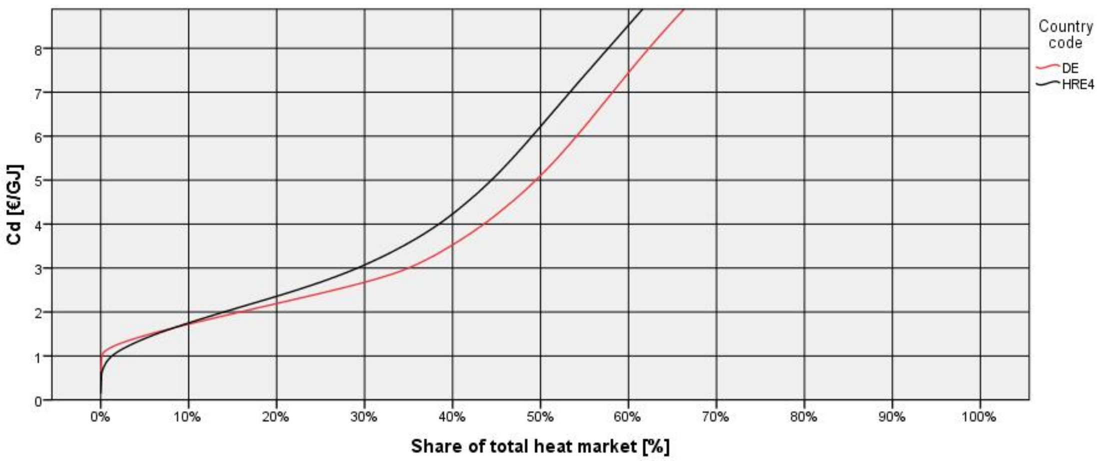

Figure 2. Marginal distribution capital cost levels (C_d) and the corresponding district heat market shares in Germany (DE), and reference curve for the 14 HRE member states.

2.2. Allocation analysis of excess heat

Excess heat from industry, waste incineration and from power plants without co-generation comprise a significant share of the current heat demand across Europe. However, a large portion of excess heat is not matched to the temporal and spatial distribution of heat demands. In order to identify the share of excess heat from above activities, which overlaps in time with heat demand of current and prospective district heating systems, and which is within a reasonable geographical distance to these, a temporal and geographical allocation analysis was carried out.

The desired outcome was quantitative input of excess heat quantities by member state, allocated from individual excess heat activities to prospective and current local district heating systems. The local nature of heat demand and supply necessitated a detailed spatial approach, which involved 2,189 excess heat activities and 52,112 prospective and current heat supply areas. An in-depth technical report has been written in the form of a scientific paper, to be presented as an archival, peer-reviewed paper at the forthcoming SDEWES-Conference in Palermo (Möller et al., To be published (2018)). In the present report, only the main considerations of the allocation process will be repeated.

The temporal allocation uses a high-resolution monthly heating degree-day dataset, from which a baseload share of climatically variable heat demand across Europe was determined. Baseload shares range between 0% and 50% of the annual heat demand, see Figure 3. A high baseload share indicates good potential to accommodate excess heat from industry and waste-to-energy plants, as these produce heat continuously. The baseload share was therefore used to identify for each prospective and current district heating system the amount of baseload excess heat, which could be accommodated in the worst case, as a conservative estimate. Seasonal variation of supply from baseload excess heat plants may be an option, but will come at higher transmission pipe investments and lower utilisation rates. The seasonal share has also been quantified for a general assessment.

Another main limitation of the share of excess heat supply, which can be used in the heating sector, is the geographical location of excess heat activities relative to heat demand. The spatial allocation has been analysed using a GIS-based network analysis, where the primary road networks form proxies for the routing of transmission pipes. These may be up to 50km long, depending on the heat rate and the local heat markets.

The ArcGIS Network Analyst was used to carry out a spatial allocation in two steps. First, baseload excess heat from industrial plants and waste incineration was allocated using a Capacitated Coverage problem solver. Here, the limited excess heat capacity, which is determined by the amounts of waste handled and the production volumes of industries, is allocated in the order of the nearest to the farthest district heating network until either the supply is spent or the maximum network distance is reached. This has proven to solve two problems of identifying a match of demand and supply at the same time: first, to make sure that this happens at least cost by minimising the network length; and second by effectively representing absolute scarcity of the resource.

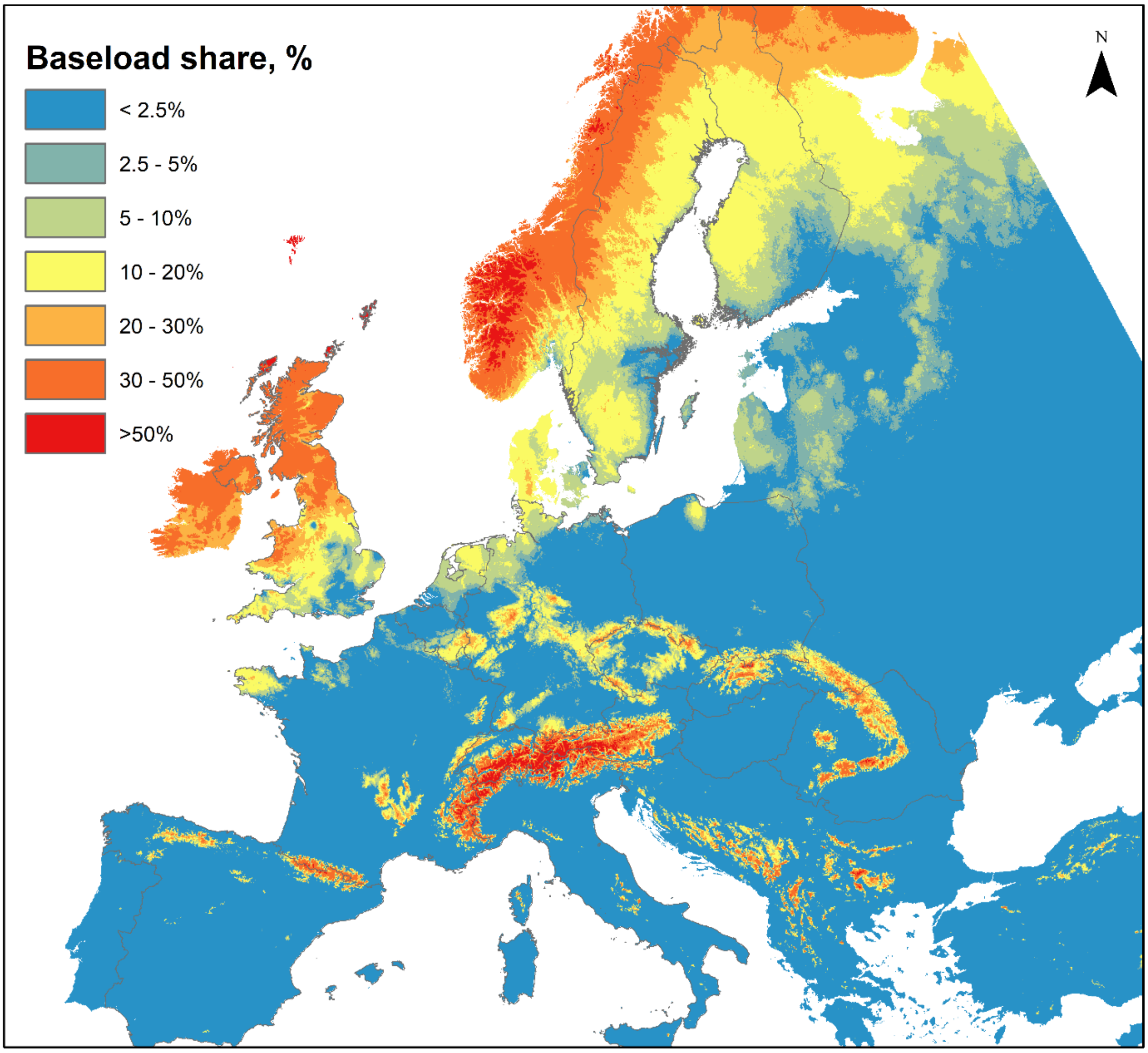

Figure 3. Baseload shares of heat demand across Europe.

In the second step, all baseload demand not covered and all the seasonal demand has been subjected to an allocation to current power-only plants. As the future capacity, type and location of European power plants is unknown, and most plants will have to face their replacement within the next decades, the allocation of fixed amounts of excess heat does not make sense in the present project.

Therefore, it was decided to reverse the objective and to identify those locations where future heat markets may emerge. Here, there is a potential to establish large agglomerations of district heating systems on the one hand, and the availability of good locations for energy conversion plants on the other. Current locations of power plants usually have access to infrastructures such as the power grid and transportation.

The allocation of potentials to develop large-scale cogeneration-based heat markets was carried out using the same network analysis approach, but solving a Minimise Impedance problem, which simply identifies all least-cost network connections within a given distance. Each connection is characterised by a length and a transmitted amount of heat. Using a pipe-dimensioning model, the annualised costs for the investment in transmission pipes were calculated using a simplified approach in order to exclude the very long and thin transmission pipes to the less attractive heat markets.

The result of the allocation is a representation of local heat markets. For subsequent percentages of heat demand (10%, 20%, 30%… 100%) in each prospective heat supply area, the following information was computed:

- Average, annualised district heat distribution capital costs
- Weighted average of district heat distribution grid efficiency
- Baseload share of gross district heat demand
- Seasonal share of gross district heat demand
- Allocated baseload excess heat demand and supply
- Unallocated baseload excess heat demand and supply
- Allocated seasonal excess heat demand and supply
- Unallocated seasonal excess heat demand and supply

In addition, available and potential renewable energy sources for district heating were identified and geographically distributed or allocated to prospective supply areas:

- Large-scale solar thermal (Trier et al., 2018)
- Priorities of exploring geothermal heat (courtesy of the GeoDH project (Dumas and Bartosik, 2014))
- Residual biomass from forestry and agriculture (courtesy of the BioBoost project (Pudelko et al., 2013))

The output of the allocation is a locally determined potential to establish district heating grids including the costs of installation; the temporally and spatially accessible excess heat from industry, waste-to-energy facilities and from current power plant locations; and the access to locally available renewable energy sources. All this combined allows for the formulation of local and national heat supply strategies by means of geographically explicit analysis. As an input to WP6, extensive database extracts with the above content were submitted to Aalborg University.

2.3. Recommended levels of district heating

A new dynamic layer, labelled "Recommended DH levels", has been added to the Peta 4.2 online web map application (see sub-section 1.2.2 above). This new layer contains recommendations to develop district heating at the local scale. For each of the 52,112 prospective supply areas (see the separate layer "Prospective supply areas (HRE4)", information about heat demand, the costs of developing district heat distribution grids, and the possible sourcing of excess heat has been collected through spatial analysis.

Recommendations are based on several criteria. First, the costs of investing in district heat distribution grids are a measure to separate the economic potential from the technical. A maximum average distribution capital cost of 5€/GJ by annual heat demand was used as a first benchmark. The district heating shares corresponding to this cost level were derived from local cost-supply curves for each supply area. The district heating shares give a first glance on recommendable district heating coverage on the local level.

Upon opening of Peta 4.2 and expanding the new layer title, the following legend appears, see Figure 4.

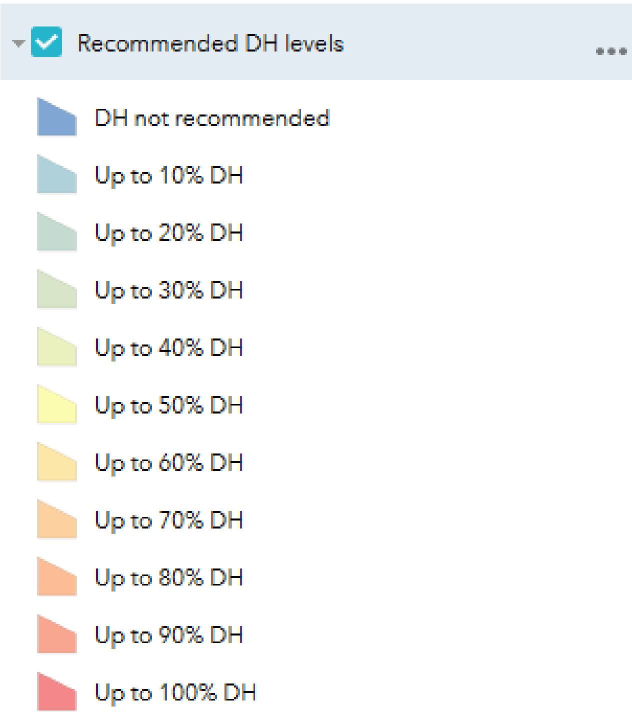

Figure 4. Legend of the new layer "Recommended DH levels" in the table of content panel of Peta.

A colour scheme from dark blue for those areas, where no or very little district heating would be feasible to develop, to dark red, where full coverage with district heating is deemed economically feasible, has been used. The layer is visible for zoom levels below

1:1.5 Mio. Upon zooming in, the layer draws semi-transparently over the layers below, or if none is chosen, the base map, see Figure 5.

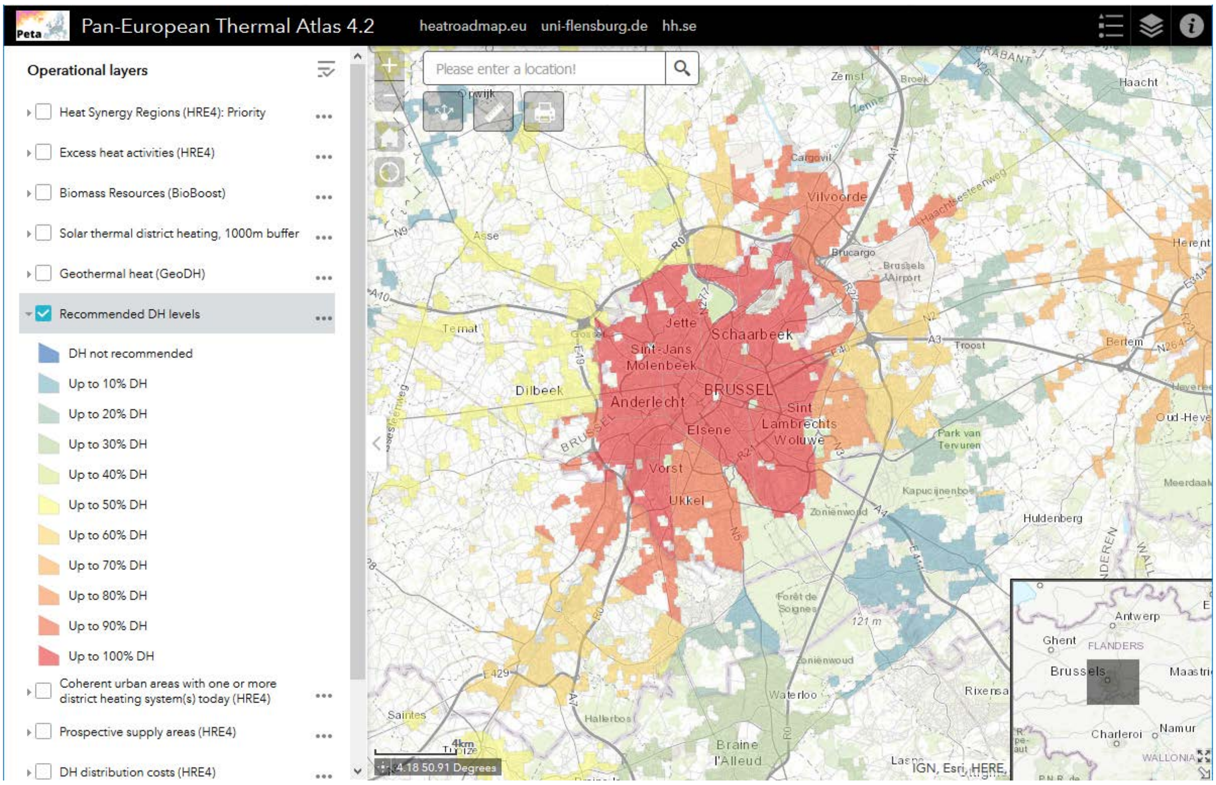

Figure 5. The layer "Recommended DH levels" for the area of Brussels.

For the process of allocation, larger cities and towns have been split to smaller districts. These appear on the map now, and different colours indicate the percentages of district heating that can be achieved for annualised average distribution capital costs below 5€/GJ annual heat delivered.

When clicking on one of the local supply areas, a pop-up window appears, which contains recommendations on the development of district heating, the access to potential excess heat sources, and the cost-sensitivity of increasing the shares of district heating continuously from zero to 100%, see Figure 6, Figure 7, and Figure 8.

Figure 6 shows the top part of the pop-up, where basic information about the location is given by the assigned place name (derived from Open Streetmaps) and the heat supply area number, which serves as a unique ID in the Peta geodatabase. Furthermore, the annual total net heat demand in 2015 is given, as well as the district heating potential below 5€/GJ as percentage of this demand.

Figure 7 shows the middle part of the pop-up with information on the efficiency of a full-scale district heating distribution grid, and returns the baseload share of heat demand as well as the hot water share, both of which tell about the potentials to integrate baseload excess heat. The pop-up also states the resulting amounts of baseload and seasonal excess heat and thus gives a recommendation for the sourcing of heat supply as well.

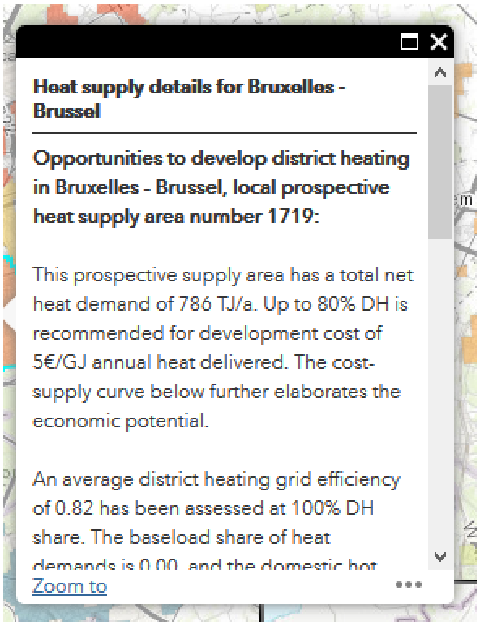

Figure 6. Pop-up window for the layer Recommended DH levels. The top part of the pop-up gives information on the location and the heat demand.

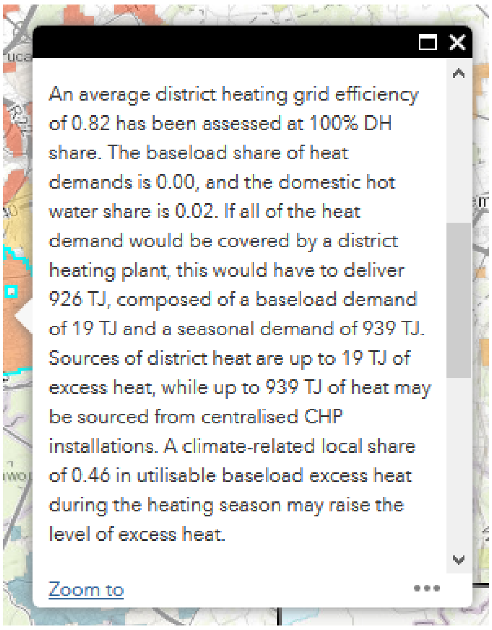

Figure 7. Pop-up window for the layer Recommended DH levels. The middle part of the pop-up gives information on the prospective local DH grid characteristics and the allocation of excess heat.

Figure 8 shows the bottom part of the pop-up, which contains a local cost-supply curve for the prospective heat supply area. A cost-supply curve shows the relation between cumulative potentials of utilising a resource, in this case the potential to develop district heating, and its average costs. The cost-supply curve for Brussels states that district heating development costs start at less than 2€/GJ annual demand, after which costs gradually increase to little less than 5 €/GJ at 90% of the potential. The final segment of the curve (each segment represents 10% of the total net heat demand to be supplied) shows a sharp increase of costs, which means that 10% of the heat market is subject to much higher costs and also higher sensitivity.

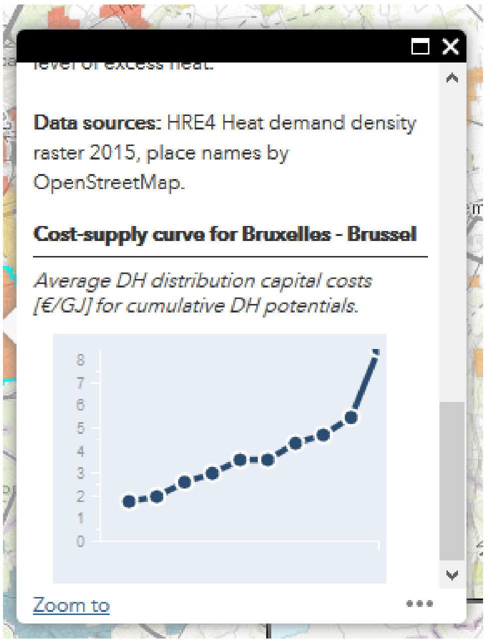

Figure 8. Bottom part of the pop-up, which shows a local cost-supply curve.

The new layer can be used to assess local heat markets from an economic perspective, and to get a first idea about the available sources of excess heat, which can be allocated to individual supply areas in a least-cost manner. This will work visually by exploring Peta 4.2 Online, but is also an integrated part of the interaction between WP2 and WP6, as all demand data on the individual prospective heat supply areas, the local cost-supply data, and the allocation results, are submitted to the energy systems analysis activities of the HRE project.

Figure 9 and Figure 10 show a regional overview on the recommended district heating levels in a more rural setting of the Münsterland area of Germany (Figure 9) and an agglomeration of urban areas (Figure 10).

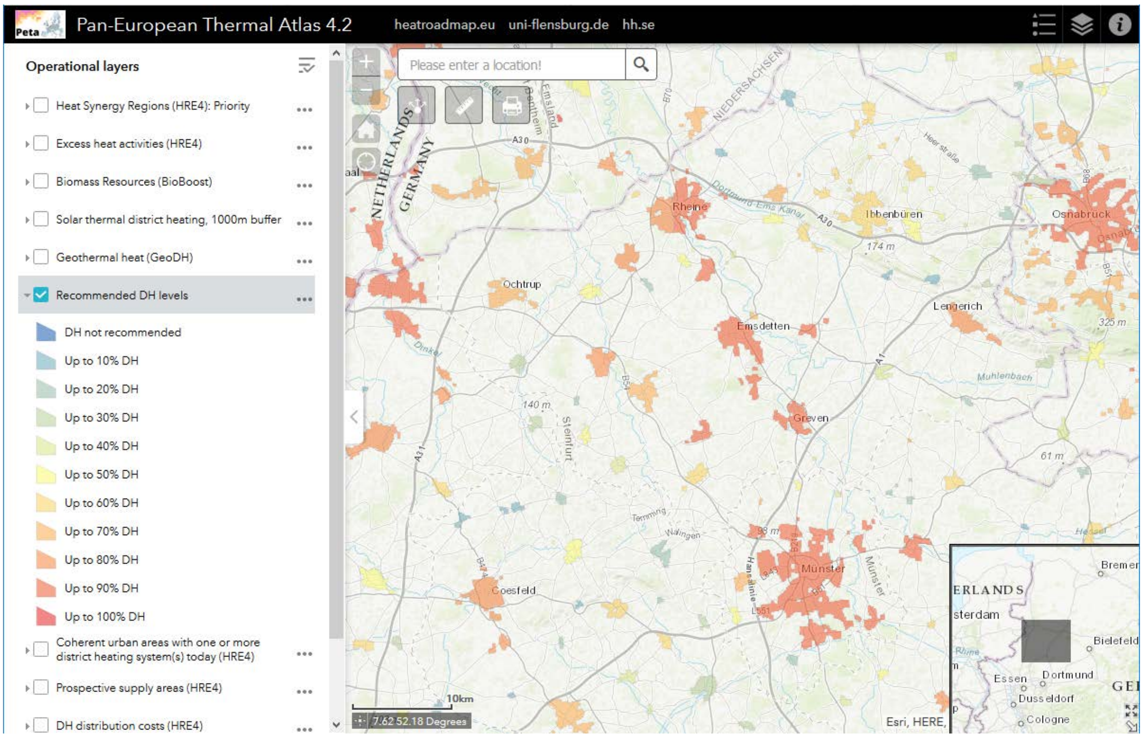

Figure 9. Recommended DH levels for the Münsterland region of Germany. Several villages, towns and cities can be seen, which have different levels of recommended DH development, based on the criterion of district heat distribution investment costs of less than 5€/GJ annual demand.

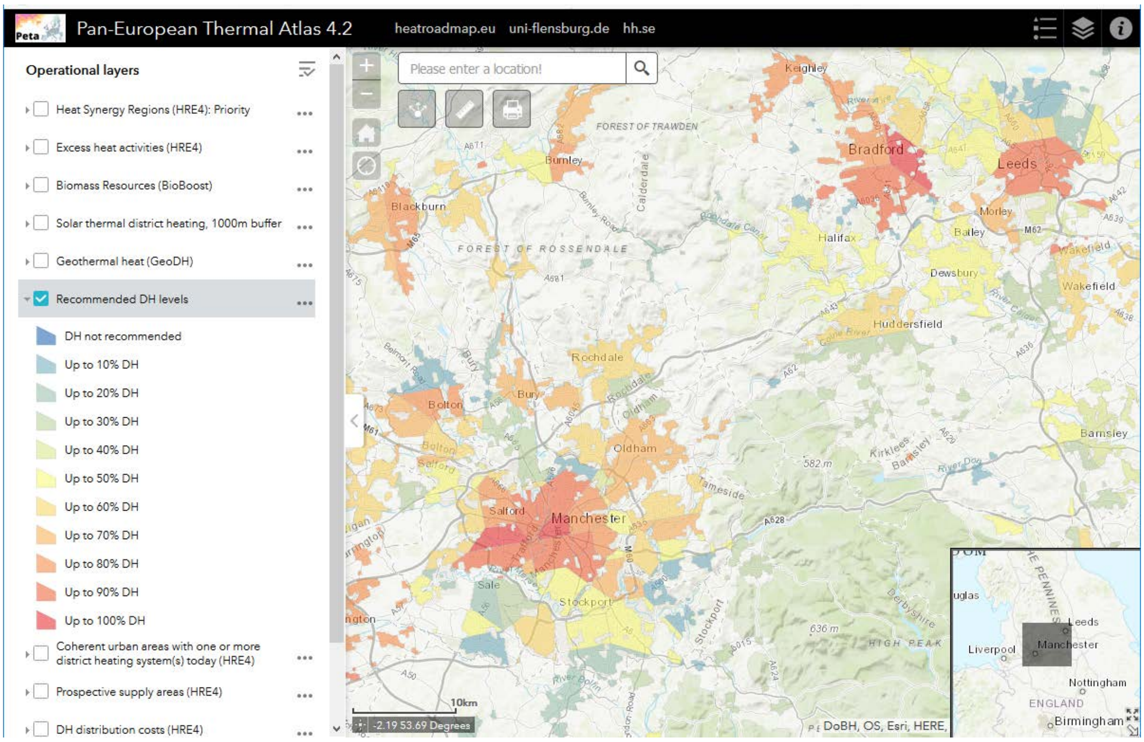

Figure 10. Recommended DH levels for the North of England, centred on Manchester and Leeds. Agglomerations of larger and coherent urban areas are visible. Because of their heterogeneous composition in terms of heat demand density, the map shows different levels of recommended DH levels based on the DH development costs.

3. Summary

This report presents in brief the development and content of the Pan-European Thermal Atlas (Peta), with focus on the current update in response to project deliverable 6.5, which concerns for the final levels of district heating for each of the 14 member states to be recommended in WP6.

The update refers to data that has been rendered in work package 2 (WP2) and consists of three main parameters: a high-resolution model of the heat demand and its density; the specific investment costs for district heating systems, and allocated volumes of industrial and energy sector excess heat for current and prospective district heating areas. All of these parameters represent spatially derived information that has been provided as data matrices to the energy systems modelling colleagues in WP6, as a basis for their assessment of national heating and cooling scenarios for the 14 member states (deliverable 6.4).

In terms of dynamic maps, a new dynamic layer, labelled: Recommended DH levels, has been added to the Peta 4.2 online web map application on August 31, 2018, where it now is publicly available. This new layer contains recommendations to develop district heating at the local scale, based on current heat demand densities, temporally and spatially accessible excess heat from industries, from waste-to-energy facilities, from current power plant locations, and in terms of access to locally available renewable energy resources.

In November 2018, the Pan-European Thermal Atlas is scheduled for a comprehensive update, rendering the third version (Peta 4.3), to be released at the 4th International Conference on Smart Energy Systems and 4th Generation District Heating conference (SES4GDH) in Aalborg, Denmark, on November 13-14. Apart from several other new dynamic layers to be introduced in this coming update (see sub-section 1.2.3), the new layer on recommended district heating levels, added here to the current Peta 4.2, will also be part of this general update.

4. References

Connolly, D., Vad Mathiesen, B., Alberg Östergaard, P., Möller, B., Nielsen, S., Lund, H., Persson, U., Werner, S., Grözinger, J., Boermans, T., Bosquet, M., Trier, D., 2013. Heat Roadmap Europe 2050 - Second pre-study for EU27. Euroheat & Power, Brussels. Available at: (http://www.euroheat.org/Heat-Roadmap-Europe-165.aspx).

Connolly, D., Vad Mathiesen, B., Alberg Östergaard, P., Möller, B., Nielsen, S., Lund, H., Persson, U., Werner, S., Nilsson, D., Trier, D., 2012. Heat Roadmap Europe 2050 - First pre-study for EU27. Euroheat & Power, Brussels. Available at: (http://www.euroheat.org/Heat-Roadmap-Europe-165.aspx).

Dumas, P., Bartosik, A., 2014. GeoDH: Geothermal DH Potential in Europe, Geo-DH project (Promote Geothermal District Heating Systems in Europe). Intelligent Energy Europe Programme. Available at (2017-08-27): http://geodh.eu/wp-content/uploads/2014/11/GeoDH-Report-D-2.2-final.pdf.

Hotmaps, 2018. Hotmaps - The open source mapping and planning tool for heating and cooling, Available at (2018-08-31): http://www.hotmaps-project.eu/.

Möller, B., Wiechers, E., Persson, U., Grundahl, L., Connolly, D., 2018. Heat Roadmap Europe: Identifying local heat demand and supply areas with a European thermal atlas. Energy 158, 281-292.

Möller, B., Wiechers, E., Persson, U., Lund, R.S., Mathiesen, B.V., To be published (2018). Heat Roadmap Europe: Towards EU-Wide, Local Heat Supply Strategies. Archival paper presented at the 2018 SDEWES Conference in Palermo.

Persson, U., Möller, B., Wiechers, E., 2017a. Methodologies and assumptions used in the mapping. Deliverable 2.3: A final report outlining the methodology and assumptions used in the mapping. August 2017, Heat Roadmap Europe 2050, A low-carbon heating and cooling strategy.

Persson, U., Möller, B., Wiechers, E., Grundahl, L., 2017b. Map of the heat synergy regions and the cost to expand district heating and cooling in all 14 MS: Accessing the outputs of D2.2, Heat Roadmap Europe 2050, A low-carbon heating and cooling strategy.

Peta_4.2, 2017. Pan-European Thermal Atlas 4.2 (Peta 4.2), Europa-Universität Flensburg, ArcGIS Online. Heat Roadmap Europe - A low-carbon heating and cooling strategy for Europe. Available at (2018-08-29): https://euf.maps.arcgis.com/apps/webappviewer/index.html?id=089b7128249e4877a3856aa14fbc1043

Pudelko, R., Borzecka-Walker, M., Faber, A., 2013. The feedstock potential assessment for EU-27 + Switzerland in NUTS-3. D1.2_v1.0, BioBoost: Biomass based energy intermediates boosting biofuel production. Co-funded by the European Commission FP7, Directorate-General for Transport and Energy. Grant No. 282873.

ReUseHeat, 2018. Recovery of Urban Waste Heat. Project number: 767429. Available (2018-08-31): https://www.reuseheat.eu/.

Stratego, 2014. Stratego - Enhanced heating & cooling plans, Web page available at (2014-10-29): (http://stratego-project.eu/).

Trier, D., Skov, C.K., Sørensen, S.S., Bava, F., 2018. Solar District Heating Trends and Possibilities. Characteristics of Ground-Mounted Systems for Screening of Land Use Requirements and Feasibility. Technical Report of IEA SHC Task 52, Subtask B – Methodologies, Tools and Case studies for Urban Energy concepts, PlanEnergi, Copenhagen.