Interreg North-West Europe
DGE-ROLLOUT

REPORT WP T1 – 2.1

Map of the spatial distribution of the heat demand at the surface.

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Content

List of Abbreviations

Country or Region Codes

BE	Belgium
BE-BRU	Brussels
BE-VLG	Flanders
BE-WAL	Walloon Region
CH	Switzerland
DE	Germany
DE-BW	Baden-Wurttemberg
DE-BY	Bavaria
DE-HE	Hesse
DE-NW	North Rhine-Westphalia
DE-RP	Rhineland-Palatinate
DE-SL	Saarland
EU	European Union (27 Member states and United Kingdom)
FR	France
IE	Ireland
LU	Luxembourg
NL	The Netherlands
SCT	Scotland
UK	United Kingdom

Others

CRS	Coordinate reference system
DGE-Rollout	Roll-out of Deep Geothermal Energy in North-West Europe
HD	Heat demand
LAU	Local administration units
NUTS	Nomenclature of territorial units for statistics
NWE	North-West Europe
QGIS	Quantum Geographic Information system
w/o	without

Introduction

The reduction of greenhouse gases is necessary to achieve the Paris Agreement goal to limit the maximum global warming by 2 °C compared to pre-industrial levels (United Nations, 2015; European Council, 2019). Space heating for residential and commercial buildings amounts to a third of the European Union's total final energy consumption with more than 4000 TWh/a (World Energy Council, 2020). Approximately 75% of the primary energy in the EU used for heating is generated by fossil fuels, resulting in high greenhouse gas emissions (Fraunhofer ISI et al., 2016). To reduce those emissions, decision makers strive to increase the market share of renewable energy sources. The project "DGE-ROLLOUT - Roll-out of Deep Geothermal Energy in North-West Europe" aims at establishing the economic use of deep geothermal reservoirs for energy generation (DGE-ROLLOUT, 2010). As a component of this project, a heat demand map is developed to determine the spatial heat demand distribution of residential and commercial buildings in North-West Europe. The heat demand map is developed by merging regional heat demand data, that are partly obtained from heat consumption data and partly calculated (Table 1). The findings of the project confirm that especially in densely populated areas like Paris, London, Brussels and the Ruhr-Rhine region, the replacement of inefficient local heating systems with an efficient central power plant has a great potential for GHG reduction. Overall, the residential and commercial sector varies between different regions, with Germany having the highest heat demand and Luxembourg the lowest. The developed maps are designed to provide a conceptual first impression for decision makers and market investors.

Table 1: Institutions/Organizations which provided heat demand data (in alphabetic order)

Bayerisches Landesamt für Umwelt
Eidgenössisches Departement für Umwelt, Verkehr und Kommunikation UVEK, Bundesamt für Energie BFE, Dienst Geoinformation
Forschungsstelle für Energiewirtschaft e.V.
Institut national de l'information géographique et forestière
Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen
Landesanstalt für Umwelt Baden-Württemberg
Ministerium für Wirtschaft, Arbeit, Energie und Verkehr
Nationaal Georegister (Netherlands)
Scottish Government, Directorate for Chief Economist, Energy Statistics
Vlaamse Overheid - beleidsdomein Omgeving - Vlaams Energie- en Klimaatagentschap

Heat demand maps

Hotmaps and Heat Roadmap Europe (HRE) are two reference projects that developed heat demand (HD) maps with a high spatial resolution on hectare level (100 x 100 m²) (Fig. 1, 2). These HD maps have been calculated applying a uniform procedure for several European countries (Hotmaps, 2016; Heat Roadmap Europe 4, 2016). While Hotmaps covers all 28 EU member states plus Norway, Iceland and Switzerland, HRE's Pan-European Thermal Atlas is available for 14 EU countries that amount to 90% of EU's total HD. Both projects use a uniform top-down approach on national HDs to determine the HD at hectare level and a bottom-up approach for the spatial distribution considering different factors like land usage and building characteristics. The resulting maps are published as homogenous interactive maps for the whole project region (Møller et al., 2018; Müller et al., 2019). The HD map for the DGE-ROLLOUT project is produced from HD data measured or calculated by each project region in North-West Europe.

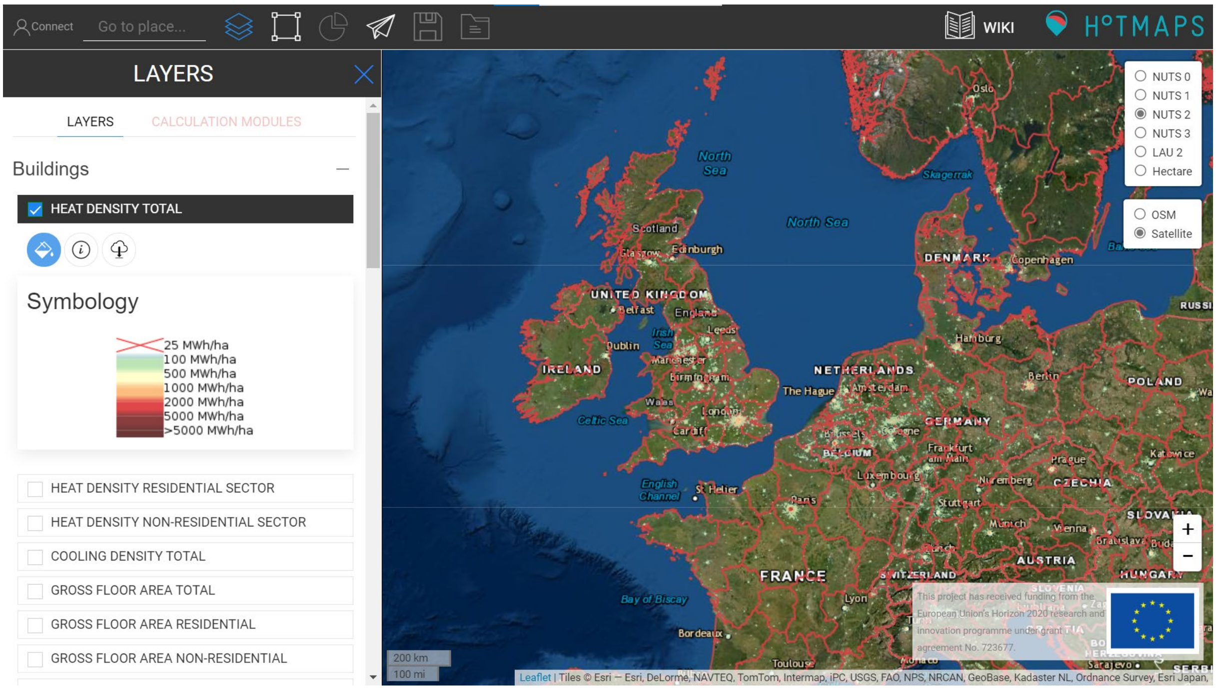

Figure 1: The Hotmaps Toolbox with the Heat Density total activated. Some of the data from this project has been used for the DGE Rollout HD map. Screenshot taken from https://www.hotmaps.eu/map on 14th December 2021.

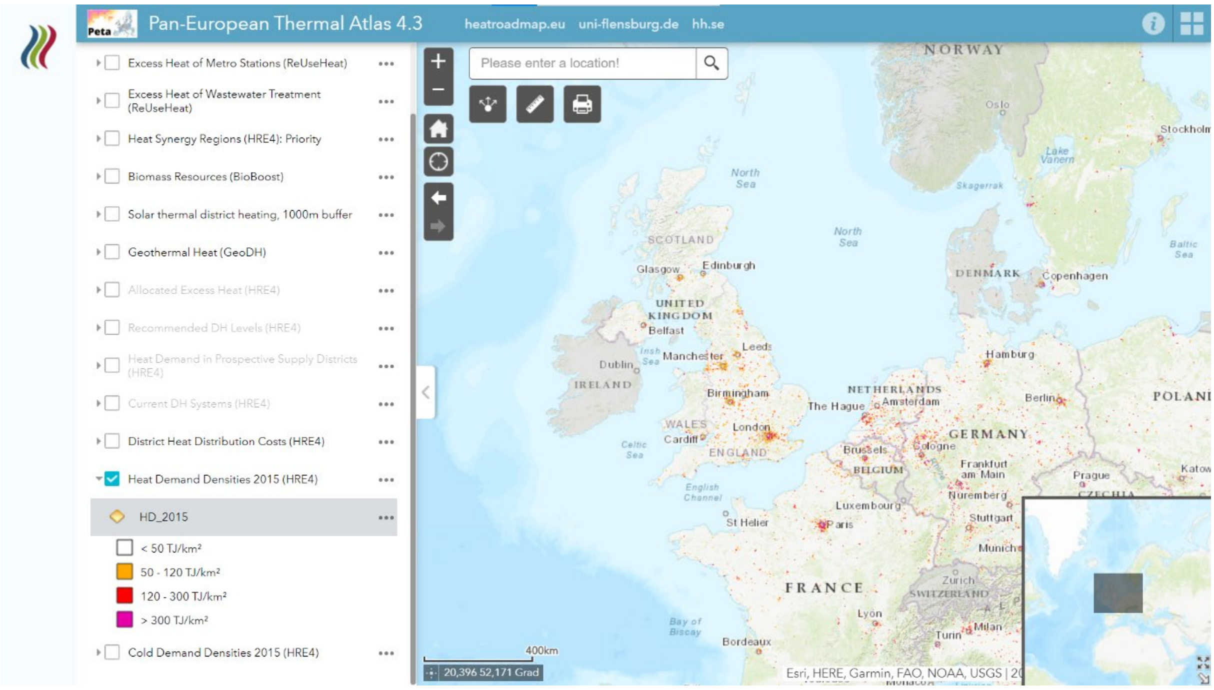

Figure 2: The Pan-European Thermal Atlas with the Heat Demand Densities activated. Screenshot taken from https://heatroadmap.eu/peta4/ on 14th December 2021.

The collected data is processed with Python and QGIS and combined in a uniform map showing the HD for space heating and hot water per hectare for residentially and commercially used areas (Van Rossum et al., 1995; QGIS Development Team, 2009). The industrial sector must be considered individually for each project and is therefore not included in this HD map. The access and usage of the HD maps varies among members states due to the different methods used. Some countries, such as France, operate a website with an interactive map and open-source data, while others do not display or publish their data. In some regions, the actual heat consumption is measured. In other regions, the heat demand is calculated with several methods using different input data such as estimated gas demand, population density or building properties. In addition, the data is prepared in different resolutions, such as HD per road segment, hectare or community.

Methodology

The development of a standardized heat demand (HD) map for the DGE-ROLLOUT project is based on existing regional HD data. The data has been obtained from project partners, authorities, and research communities, which are responsible for the publicly available heat demand maps. The received raw data is reprocessed to achieve a standardized uniform map.

It is necessary to select an interoperable data format for the development of the DGE-ROLLOUT HD map to avoid future incompatibilities while processing (Table 2). Since the received raw data is usually provided in a regional coordinate reference system (CRS), it has been transformed into the CRS used by DGE-ROLLOUT first.

Table 2: Standardized parameters used for the DGE-ROLLOUT HD map.

	Format parameters	Description
Data Type	Open Geospatial Consortium GeoTIFF Standard	Strong software support by commercial and open-source GIS software programs (Lynnes et al., 2016).
CRS	EPSG:3034, ETRS89-extended / Lambert Conformal Conic CRS	Recommended by European Commission and used by the geological survey of DE-NW as lead partner organization (European Comission, 2001).

The QGIS Standalone long-term release, version 3.16, and Python, release version 3.9.0, are used for processing the data (QGIS Development Team, 2009; Van Rossum and Drake Jr., 1995). QGIS is used to perform simple spatial operations to verify the processability of the generated data. For advanced geospatial operations, Python and Jupyter Notebook, a browser-based integrated development environment, are used (Kluyver et al., 2016).

Spatial representation and quality categories

The provided HD data can be summarized into two categories of quality and four categories of spatial presentation. The quality depends on whether the provided raw HD data is calculated or originate from billing data (Fig. 3).

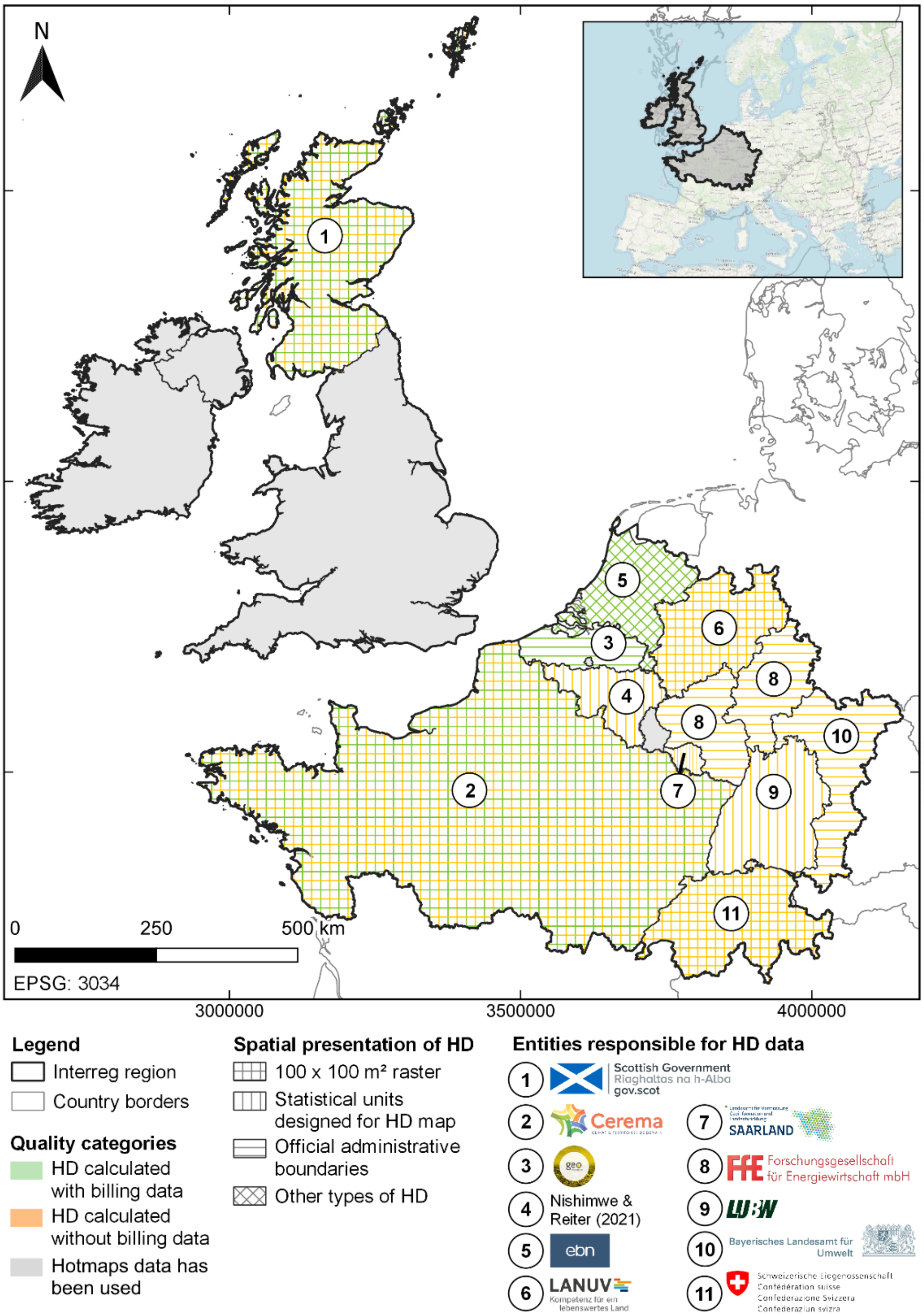

Figure 3: The Interreg region and the quality and spatial representation categories of each raw HD data delivered by the responsible entities.

Spatial representation category 1: Raster data

Regions that provided data for this category:
France, North Rhine-Westphalia (Germany), Scotland, Switzerland

The raw data received from the countries listed above are already displayed as a grid with a spatial resolution of 100 x 100 m² or, in the case of Scotland, 50 x 50 m² (Fig. 4, step 1). To handle raw data covering areas larger than the Nomenclature of Territorial Units for Statistics 1 (NUTS1), the data is first divided into smaller areas. The data sets are then reprojected and transformed to align them with the predefined CRS. An analysis mask of the region, consisting of 100 x 100 m² polygons, has been created (Fig. 4, step 2). The raw HD data is then assigned to the mask-polygons using the area share inside these mask-polygons (Fig. 4, step 3).

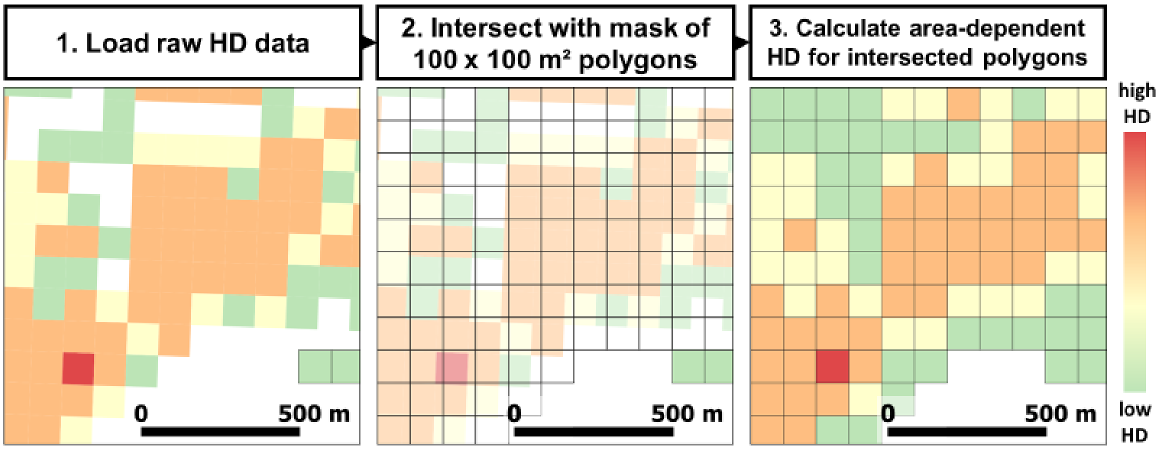

Figure 4: Processing of raw data category 1. To align with already processed data, the loaded raw data (regional CRS) is intersected with a mask of polygons (project CRS).

Spatial representation category 2: Statistical units

Regions that provided data for this category:
Flanders (Belgium), Baden-Wurttemberg (Germany), Saarland (Germany)

Buildings of similar age classes and energy requirements are grouped as one statistical unit (Fig. 5, step 1). These datasets have to be rasterized similar to the data of spatial representation data type 1 (Fig. 5, step 2 & 3).

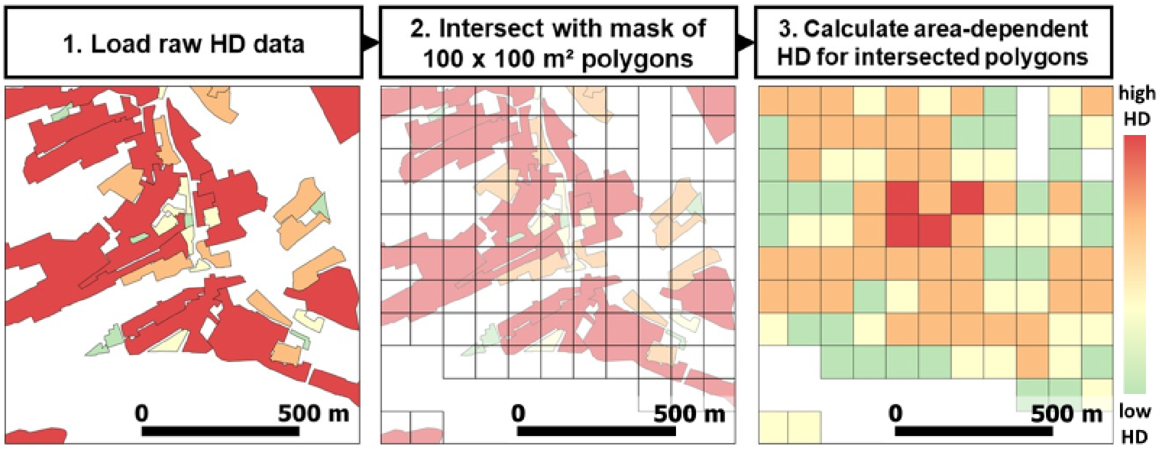

Figure 5: Processing of raw data category 2. To align with already processed data, the loaded raw data polygons are intersected with a mask to get its proportionate heat demand per polygon.

For the Flanders region in Belgium, the raw data has been provided as the associated heat consumption based on road segments and adjacent buildings (Fig. 6, step 1). The share of road segments has therefore been calculated instead of the share of area inside the mask-polygons (Fig. 6, step 2 & 3).

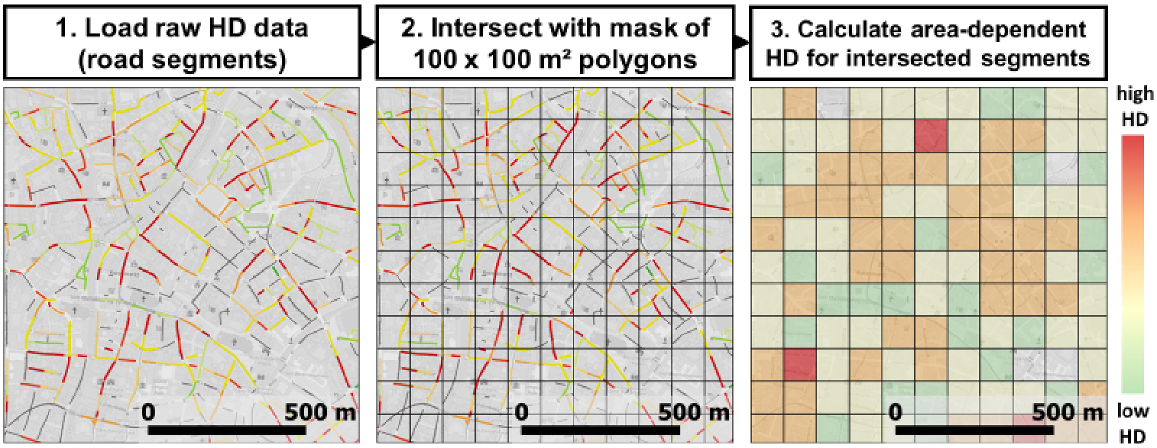

Figure 6: Processing of raw data category 2 for Flanders (Belgium) with road segments as input data. Basemap provided by OpenStreetMap, 2021.

Spatial representation category 3: Official administrative units

Regions that provided data for this category:
Walloon (Belgium), Bavaria (Germany), Hesse (Germany), Rhineland-Palatinate (Germany)

The HD data is provided as a point layer, which contains the sum of the HD for regions at the Local Administration Units (LAU) level (Fig. 7, step 1 (a)).

To increase the resolution to 100 x 100 m² the Hotmaps HD data is used (Fig. 7, step 1 (b)). These Hotmaps data is summed up for each community and then compared with the provided raw HD data.

$$q_{scale} = \frac{HD_{provided}}{HD_{\Sigma Hotmaps}} \quad (1)$$

Equation (1) defines the scale factor (q_{scale}) for each LAU region as the raw HD data ($HD_{provided}$) divided by the Hotmaps HD data ($HD_{\Sigma Hotmaps}$). Every Hotmaps HD raster cell is then multiplied with this scale factor (Fig. 7, step 2). This process increases the spatial resolution from the provided raw HD data (Fig. 7, step 3).

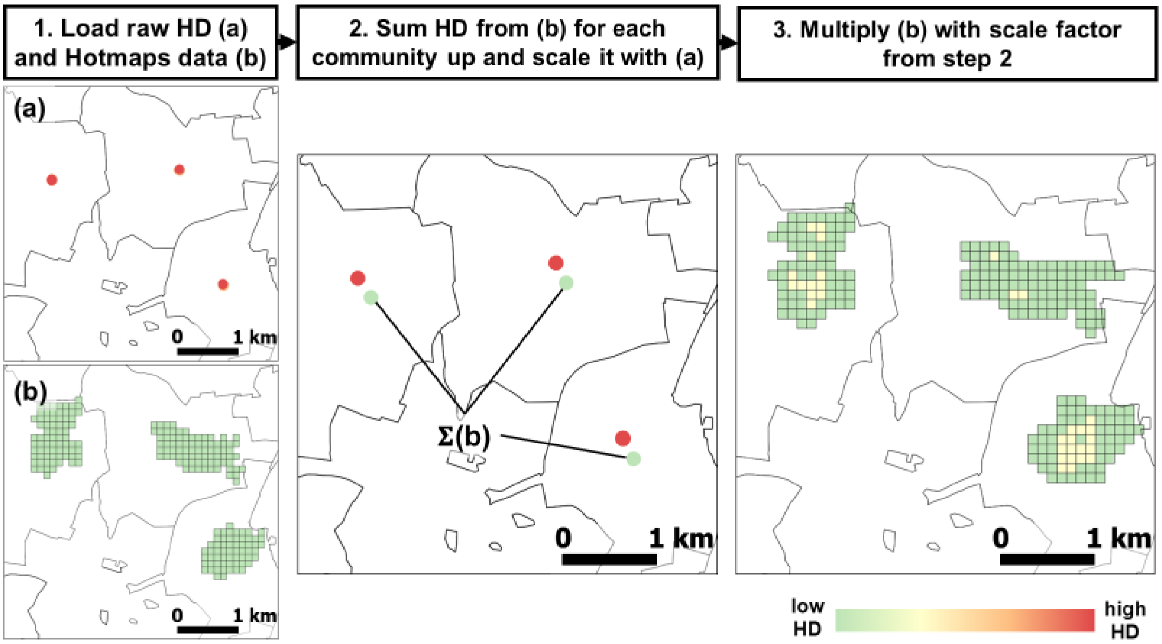

Figure 7: Processing of raw data type 3. The spatial resolution of the input HD point layer has been increased using the spatial HD distribution from Hotmaps.

Spatial representation category 4: Other forms of representation of the HD

Regions that provided data for this category:
The Netherlands, Walloon (Belgium)

The calculation of HD for the Netherlands is based on the absolute gas demand per postal code area (Fig. 8, step 1). Gas is used for 84% of heat generation in the residential sector and as a total energy carrier (CBS (a), 2021; CBS (b), 2021). Equation (2) has been defined to transform the gas demand into a HD:

$$HD_{NL} = \frac{CV_{net} * SH * HW}{3600} * GD_{NL} \qquad (2)$$

HD_{NL} refers to HD in the Netherlands in MWh/ha. GD_{NL} is the gas demand in m³/a. CV_{net} is the net calorific value of natural gas, which is set at 31.65 MJ/m³ for this region (Zijlema, 2021). Since the calorific value is given in MJ, it has been divided by 3600 to get MWh. SH and HW are the percentage of gas used for space and hot water heating; according to literature it is set to 72% and 23% respectively (Majcen, Itard & Visscher, 2013). The methodology used in Fig. 8, step 2 & 3 is described in chapter 2.1.1: Spatial representation category 1: Raster data.

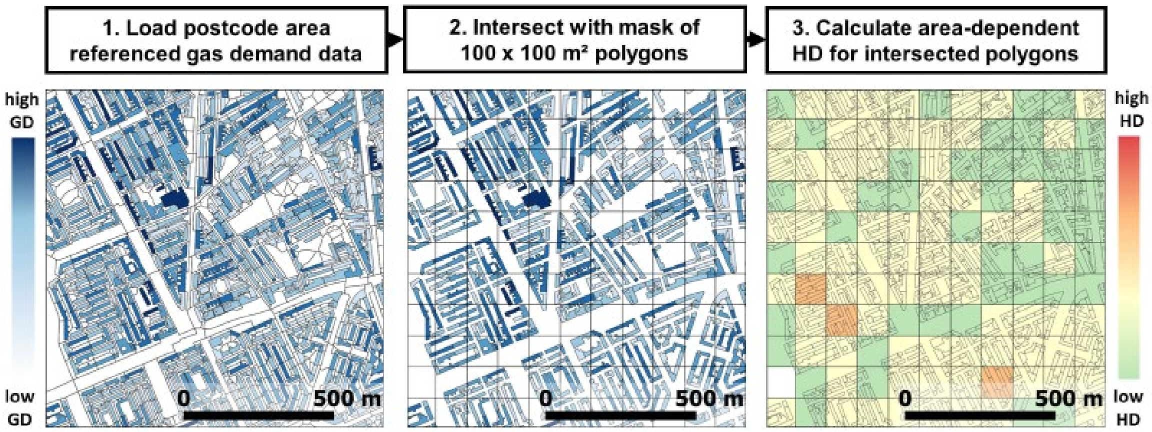

Figure 8: Processing of the gas demand (GD) data of the Netherlands. The postal code (neth. “postcode”) areas have a spatial resolution on building level. Polygon-Layer provided by Geofabrik, 2021.

The HD data has been provided in the form of image data (Fig. 9, step 1) (Nishimwe & Reiter, 2021). This image is then georeferenced and the color codes of each statistical sector are extracted as a point layer (Fig. 9, step 2). The HD is assigned to each point according to color values in the given legend (Fig. 9, step 3). This point layer is used as the input for processing as described in chapter 2.1.1: Spatial representation category 1: Raster data.

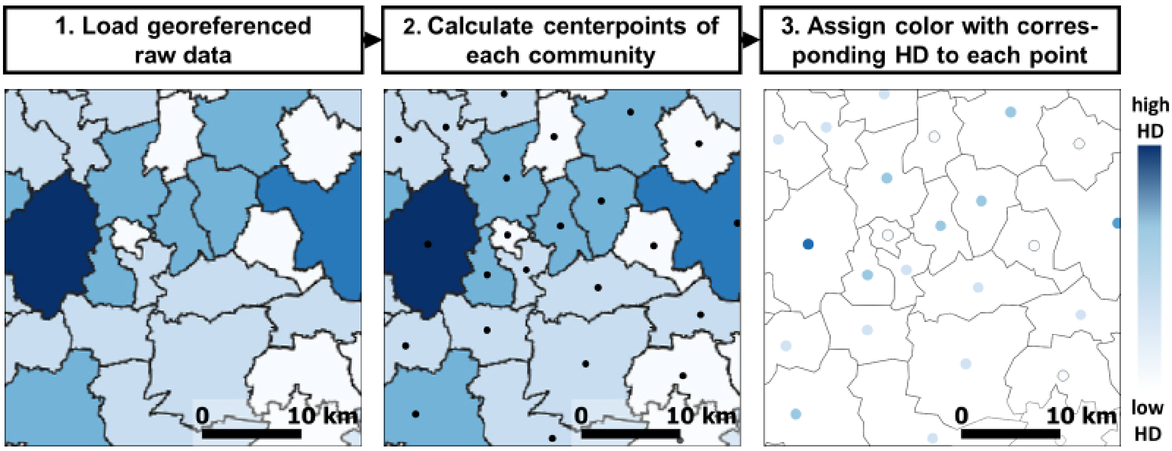

Figure 9: Processing of the Walloon region data. The bluish color scheme is set by the raw data.

Regions with no HD data

Regions that has not provided HD data:
Brussels (Belgium), Luxembourg, Ireland, UK (except Scotland)

Hotmaps HD data has been used for regions that have not provided any raw HD data. Since Hotmaps data is given with a high spatial resolution of 100 x 100 m² raster cells in a different CRS, the methodology is identical as described in chapter 2.1.1: Spatial representation category 1: Raster data.

Results: DGE-ROLLOUT heat demand maps

The three maps developed in this work show the HD in MWh/ha over one year for the residential and commercial sector and the summed-up HD of both sectors (Fig. 10, 11, 12). HD values below 15 MWh/ha are not displayed in the maps, due to calculation inaccuracy and low significance for investment projects. All three maps show similar structures in the distribution of heat demand with accumulations in the same conurbations. Standout areas with high HD and concentrated accumulations are London (England), Paris (France), Brussels (Belgium) and the Rhine-Ruhr region (Germany). The residential HD map shows evenly lower values compared to the ones in the total heat demand map, while in the commercial heat demand map values below 50 MWh/ha have a significant lower share. There is no data with subclassification for the different sectors in Scotland, so it is not shown in the residential and commercial heat demand maps.

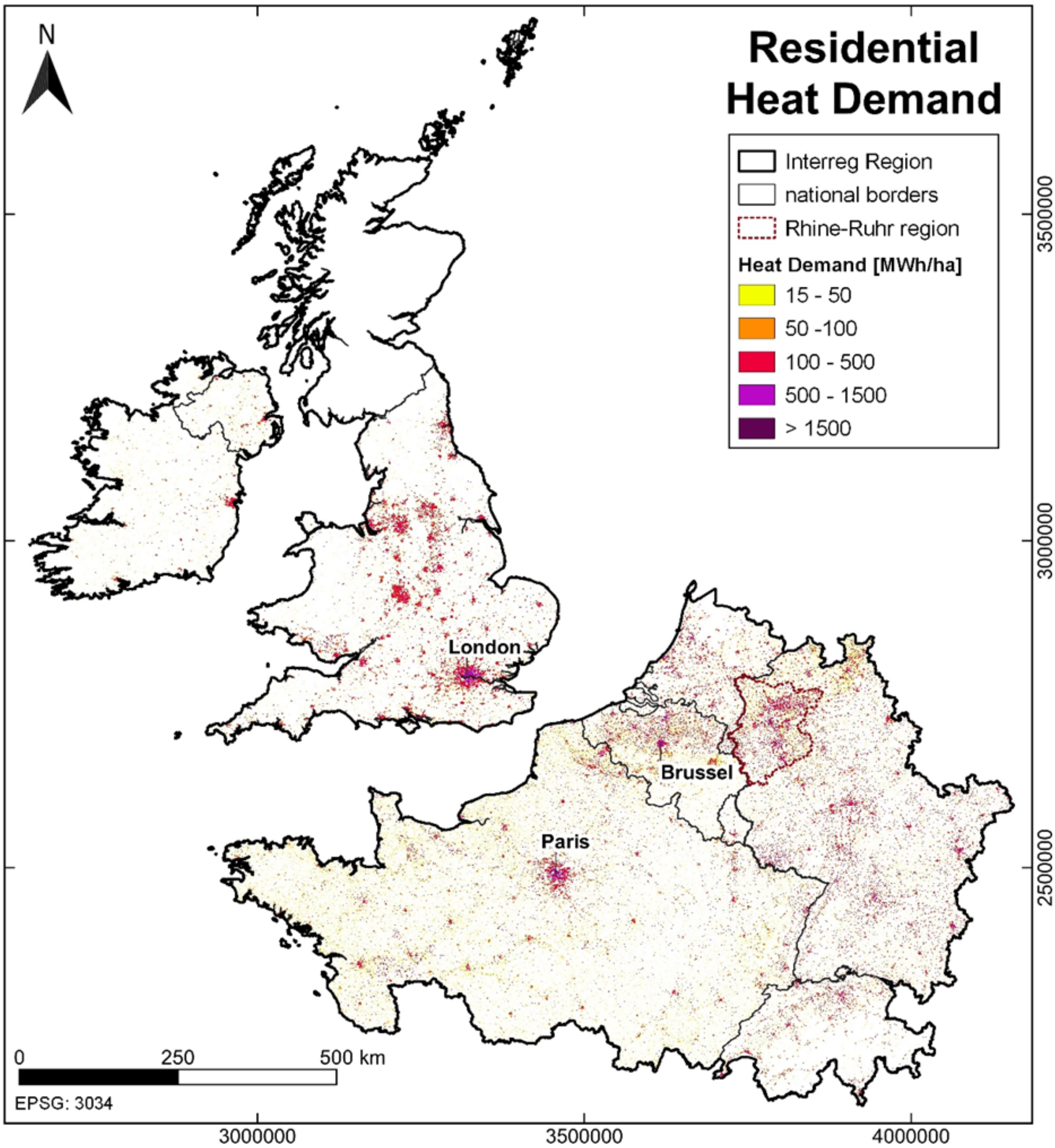

Figure 10: Heat demand in MWh/ha per year of the Interreg region for the residential sector.

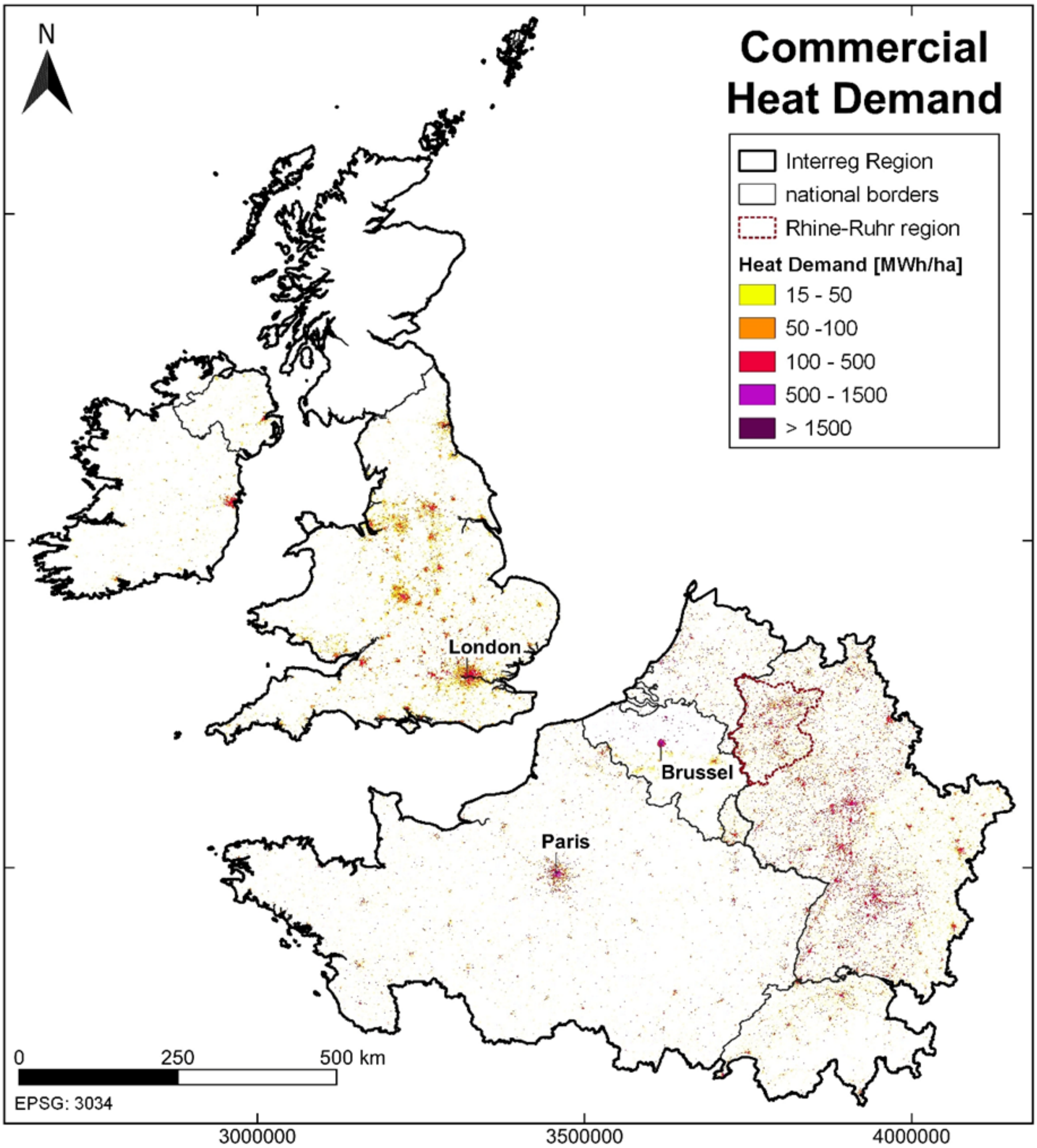

Figure 11: Heat demand in MWh/ha per year of the Interreg region for the commercial sector.

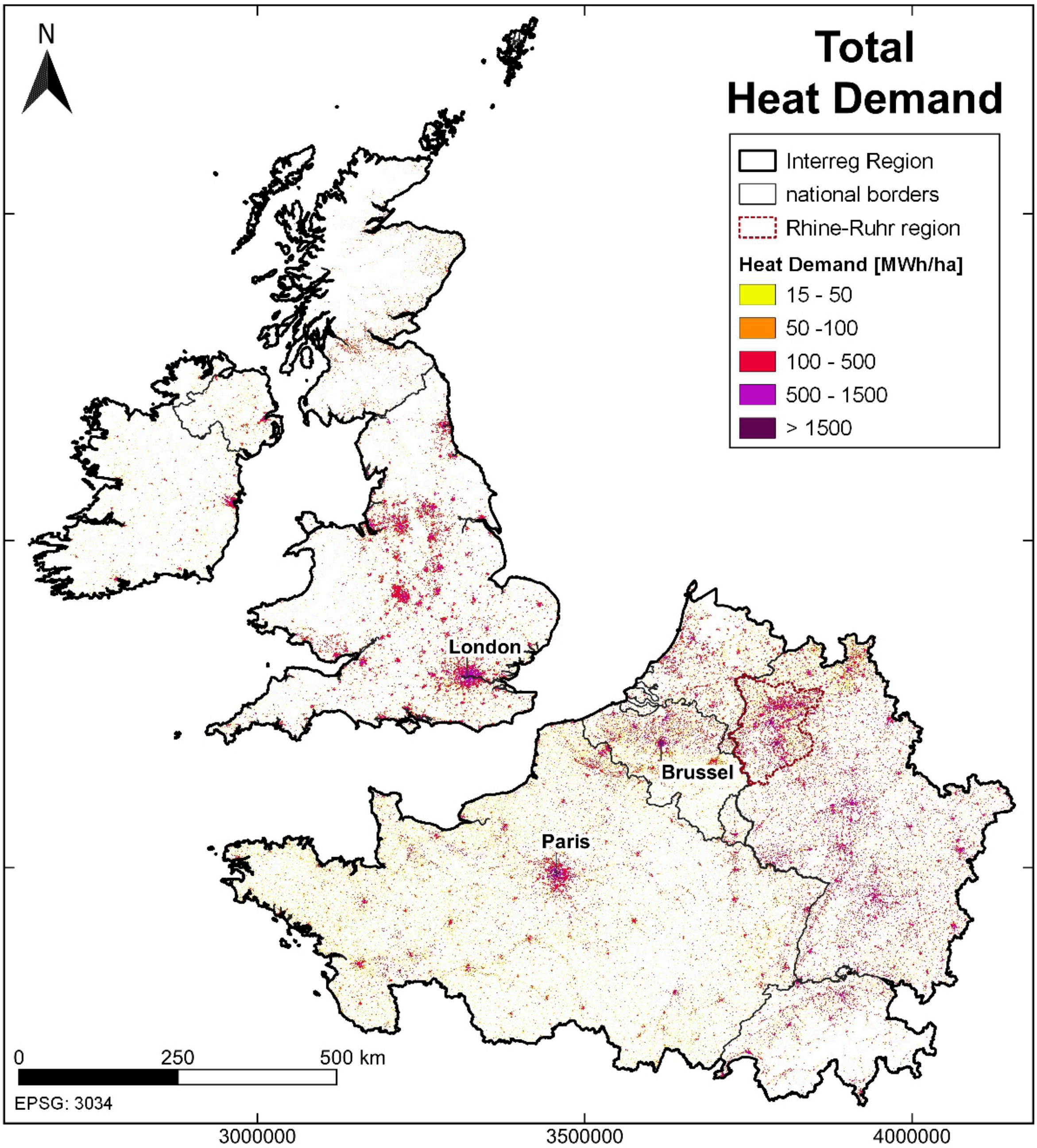

Figure 12: Total heat demand in MWh/ha per year of the Interreg region. “Total” is the summed heat demand for each 100x100 m² raster cell of the previous shown residential and commercial sectors.

Residential heat demand map

In the residential map the HD appears to be more evenly distributed over the surface. In very rural areas such as in Ireland, the residential HD also is more pronounced in hotspots, that are linked to more densely populated areas. The residential sector contributes generally more to the regional heat demand of each country or region than the commercial sector, with the largest share in the UK without Scotland (76%) and the smallest in Germany (44%). On average the residential sector contributes to

68% of the heat demand of each region. No link between country share of total heat demand of the Interreg region and distribution of residential and commercial sector of the HD of each country can be seen (symbolized as the diagram's size in Fig. 13).

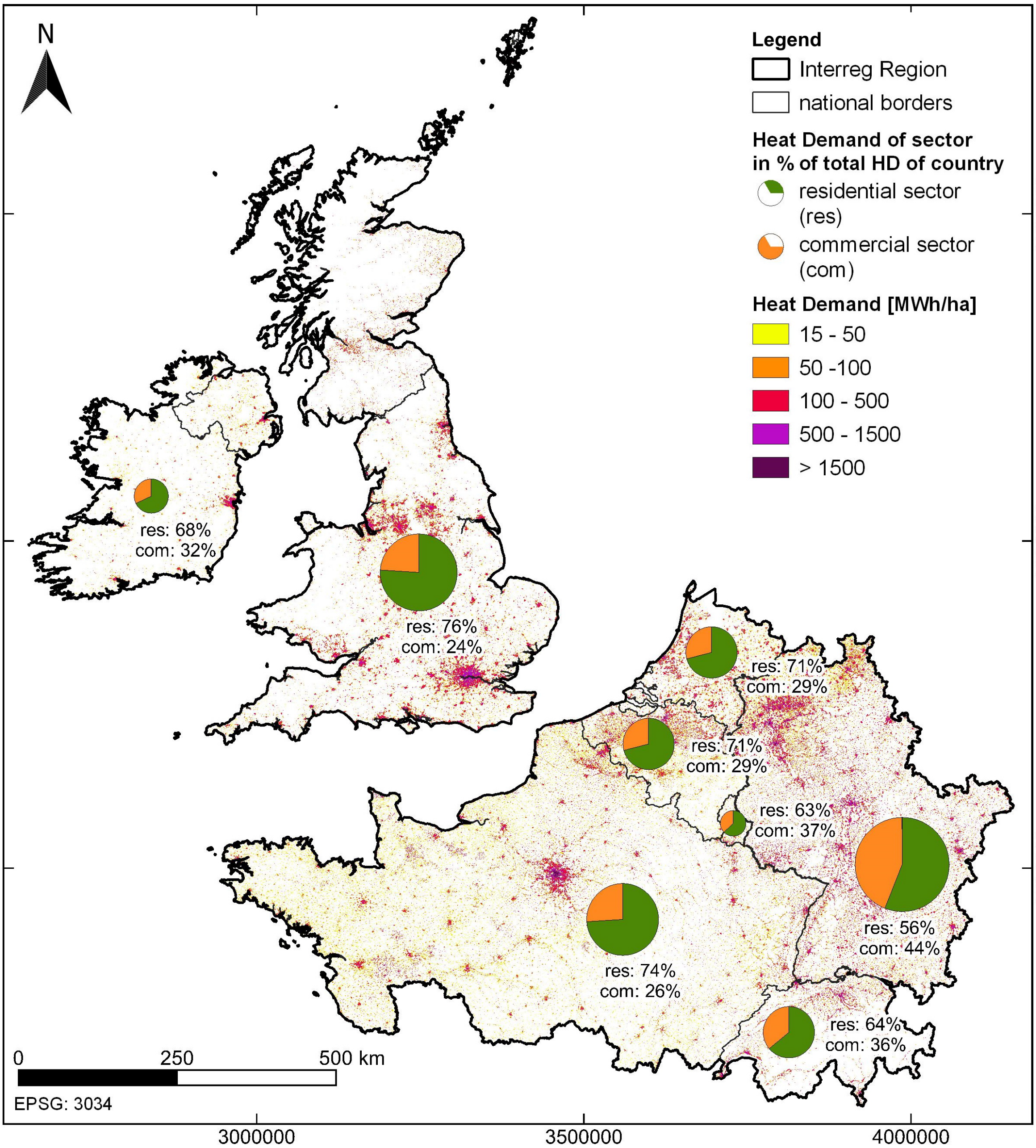

Figure 13: Share of residential and commercial sector in heat demand of each country in the Interreg region, in %. Size of diagram symbolizes country share of total heat demand of the Interreg region. Underlaying map: total heat demand.

Commercial heat demand map

Particularly in the commercial HD map, the demand appears to be more concentrated primarily in urban regions. In the UK without Scotland, the share of the commercial sector of HD varies the least with level of urbanization (Fig. 14). For Belgium, Switzerland and France, an increase in the commercial sector's share of HD can be seen with higher level of urbanization. In Ireland, the share is nearly 70% greater in cities than in suburbs or rural areas. In contrary, the share in Luxembourg decreases with the degree of urbanization. In the Netherlands, the share of the commercial sector in HD is highest in towns and suburbs. In Germany, the difference between the share of the residential sector and the commercial sector in the HD per degree of urbanization is the smallest of all regions (DEGURBA, 2020).

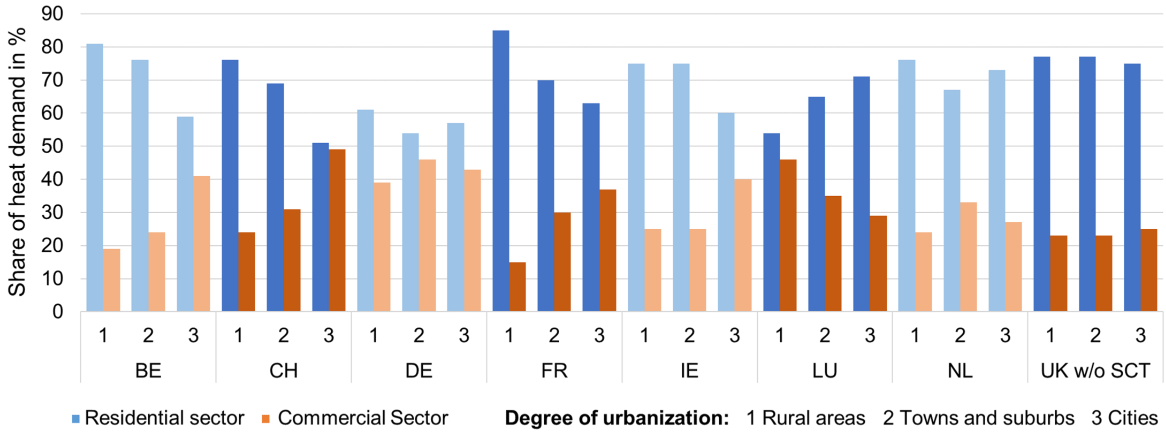

Figure 14: Share of residential and commercial sector in heat demand depending on degree of urbanization in each country, 1: Rural areas 2: Towns and suburbs 3: Cities (DEGUBRA, 2020).

Total heat demand map

The total HD of the Interreg region amounts to about 1700 TWh. Germany and Great Britain have a greater share of HD values above 100 MWh/ha and therefore appear darker in the HD maps compared to other regions. Both countries have the highest HD in the Interreg region; with 607 TWh and 423 TWh, respectively. Germany (35 %), the UK without Scotland (24%) and France (21%) are accountable for 80% of the total HD (Fig. 15). The remaining 20% go to Belgium, Switzerland, the Netherlands, Ireland and Scotland. Luxembourg's HD accounts for less than 1% and is therefore not displayed. The distribution of country shares of HD in the Interreg region is similar for both sectors.

a)

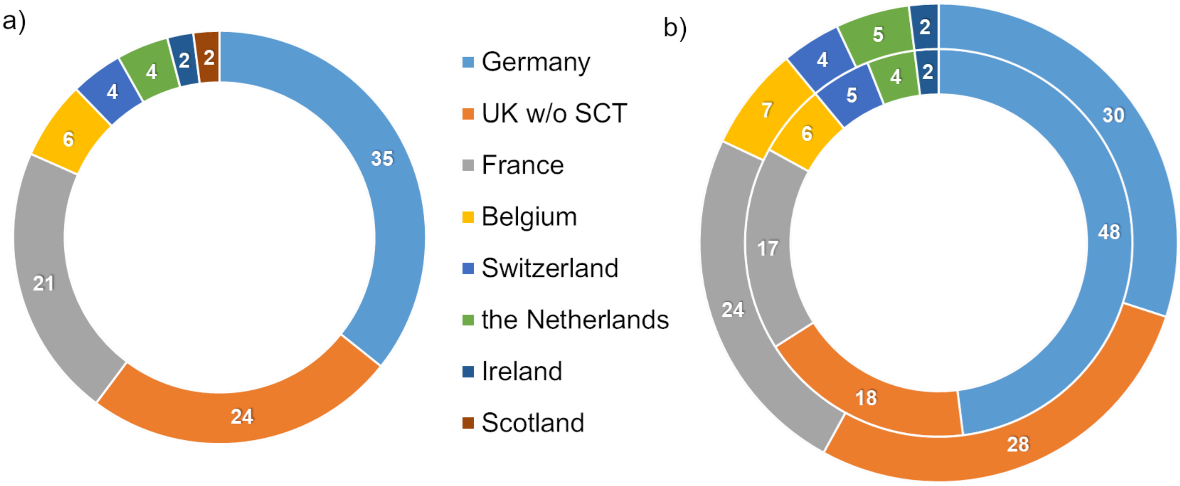

Figure 15: (a) Country share of Interreg total heat demand for residential and commercial sector. (b) Country share of Interreg heat demand per sector, in % (the outer circle refers to the residential heat demand and the inner circle to the commercial heat demand). There is no data with subclassification for the different sectors for Scotland.

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