sEEnergies

QUANTIFICATION OF SYNERGIES BETWEEN ENERGY EFFICIENCY FIRST PRINCIPLE AND RENEWABLE ENERGY SYSTEMS

D5.5

Geographic layers that illustrate future energy efficiency potentials

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 846463.

Project

Acronym	**sEEnergies**
Title	Quantification of Synergies between Energy Efficiency First Principle and Renewable Energy Systems
Coordinator	Brian Vad Mathiesen, Aalborg University
Reference	846463
Type	Research and Innovation Action (RIA)
Programme	HORIZON 2020
Topic	LC-SC3-EE-14-2018-2019-2020 - Socio-economic research conceptualising and modelling energy efficiency and energy demand
Start	01 September 2019
Duration	34 months
Website	https://seenergies.eu/

Consortium	**Aalborg Universitet (AAU)**, Denmark **Hogskolan i Halmstad (HU),** Sweden **TEP Energy GmbH (TEP),** Switzerland **Universiteit Utrecht (UU),** Netherlands **Europa-Universität Flensburg (EUF),** Germany **Katholieke Universiteit Leuven (KULeuven),** Belgium **Norges Miljø- og Biovitenskapelige Universitet (NMBU),** Norway **SYNYO GmbH (SYNYO)**, Austria **Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. (Fraunhofer),** Germany

Deliverable

Number	**D5.5**
Title	**Second set of map layers (future years scenarios for 2030 and 2050)**
Lead beneficiary	EUF
Work package	WP5
Dissemination level	Public (PU)
Nature	Other (O)
Copyright license	CC BY 4.0
Due date	28.02.2022
Submission date	07.03.2022
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Document history

Version	Date	Comments
0.1	18.02.2022	Draft sent to reviewer
0.2	07.03.2022	Report submitted

Acknowledgement: This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 846463.

Executive Summary

The Pan-European Thermal Atlas Peta is an online visualization tool for spatial data. Version 5.1 was launched in 2020 with a first set of layers for the EU27+UK, which related to energy demands in the base year and first, intermediate project results regarding energy efficiency potentials. With the update to version 5.2, Peta was complemented with layers based on the scenarios studied in different sEEnergies tasks, completed after the launch of Peta 5.1. As a result, Peta 5.2 shows energy demand and energy efficiency data for residential and service sector buildings as well as for industry and transport for different scenarios, focusing on the status-quo and the scenario year 2050, while also containing 2030 data.

Throughout the Heat Roadmap Europe projects, Peta has been developed as an information system for the heat sector. Its main content related to district heating grid investment costs, district heating area demarcations and supply options. The current version 5.2 features new layers that include future heat demands and district heating development costs for distribution and service pipe investment costs, as well as energy efficiency potentials of the industry and transport sectors.

In a new layer group Peta 5.2 presents the results of spatial analyses, for example the allocation of excess heat to urban areas as well as an index that combines energy efficiency potentials across sectors and technologies.

Peta 5.2 is referenced as (Peta 5.2, 2022) and can be accessed via the following URL: https://tinyurl.com/peta5seenergies, while the geospatial data can be accessed through the sEEnergies Open Data Hub: https://s-eenergies-open-data-euf.hub.arcgis.com/ (sEEnergies Open Data Hub, 2020). Furthermore, Story Maps (sEEnergies mapping team, 2022) add an additional dimension to the dissemination of project results (accessible here: https://tinyurl.com/sEEnergiesStorymaps).

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Acronyms & Abbreviations

Term	Description
BL	Baseline (scenario)
D	Deliverable
DHDCC	District Heating Distribution Capital Costs
EU27+UK	27 European member states plus the United Kingdom
FE	Frozen Efficiency (scenario)
GeoDH	GeoDH project
HRE4	Heat Roadmap Europe project
Peta	Pan-European Thermal Atlas
UA	Urban Areas as defined in D5.2 (Wiechers, Möller, & Persson, 2020)
WP	Work package

1 Introduction

The Pan-European Thermal Atlas (Peta) is an interactive web-mapping application originating from the Heat Roadmap Europe project series (HRE, 2018). In the sEEnergies project (sEEnergies, 2020), it has been developed further into a spatial information system for the geography of energy efficiency potentials in the building, transport, and industry sectors, as well as for the associated infrastructures and synergies.

1.1 Objectives and development story of Peta

Energy demands and efficiency potentials are geographically distributed, with consumption and supply patterns present and visible at small scales of geographical resolution. Peta addresses the need to locate, map, and quantify, the nexus of end-use energy efficiency and efficient energy infrastructures. By combining information on building, transport, and industrial sectors in a common geospatial reference system, synergies between efficiency measures in the sectors can be analysed spatially. Examples are:

a) Usage of excess heat of industrial plants or energy conversion processes in district heating systems where the use of primary energy supply sources to meet heat demands in energy efficient buildings are reduced significantly.
b) Impact of urban development and the location of buildings on corresponding heat demand density concentrations, as well as on transport demands, modes of transportation, and resulting energy demands.

Furthermore, the overall energy efficiency improvement potential in any given area can be expressed as an index, which combines location-specific assessments of various demands, assets, and opportunities for improved efficiencies, with impacts on the supply side. Peta therefore provides the means for quantifying cross-sectoral efficiencies for integrated systems.

Future demands in buildings, transport, and industry, will be subject to economic and demographic development, the implementation of energy efficient technologies, and of human behaviour. While sectoral demand projections exist on the national scale, the local conditions determine their feasibility. Peta illustrates the local efficiency potentials and their geographical context.

The new Peta 5.2 (second update of the fifth version) is the result of a continued development towards higher geospatial resolution, the inclusion of more variables in the modelling, a broader coverage of technologies and sectors, and the introduction of future aspects.

The first two versions of the Pan-European Thermal Atlas (Peta 1 and Peta 2) were developed during the so-called Heat Roadmap Europe pre-studies in 2012 (Connolly et al., 2012) and 2013 (Connolly et al., 2013), but were never organised as online web maps. All outputs were rendered as images and paper maps at this early stage. One important milestone from this period was the first comprehensive European heat atlas, at the square kilometre level, which was published *inter alia* in (Connolly et al., 2014).

The next version, Peta 3, was associated with the IEE project Stratego (sometimes referred to as Heat Roadmap Europe 3) (Connolly et al., 2016; Cornelis, Holm, Lauersen, & Lygnerud, 2016; Möller & Werner, 2015; Persson, 2015; Stratego, 2014), where supply mapping and further work to assess

residential and service sector heat demands at the hectare level continued. This led, among other things, to the first attempts at 1-hectare heat demand raster representations, and Peta 3 was also the first to go online (using Mango Maps technology, now deprecated).

From 2016 and onwards to 2019, the fourth version of the Peta was developed within the context of the H2020-project Heat Roadmap Europe 2050 (HRE, 2018). Overall, Peta 4 came in three updates (Peta 4.1, Peta 4.2, and Peta 4.3), where the last (Peta 4.3) remains publicly available today, as shared by the HRE4 project website (Peta 4.3, 2018). The main innovations during this period were a further developed mapping of industrial and commercial excess heat resources, district heating investment costs calculated at hectare levels, the concept of PSD (Prospective Supply Districts) first introduced, and the mapping of heat supply strategies (Möller, Wiechers, Persson, Grundahl, & Connolly, 2018; Möller et al., 2019; Persson, Möller, & Werner, 2014; Persson, Möller, & Wiechers, 2017; Persson, Wiechers, Möller, & Werner, 2019).

The new version and the latest update of Peta, Peta 5.2, allows users to show map layers structured by sector (residential and service-sector buildings, industry, and transport). It facilitates the visualisation and analysis of inter-sectoral aspects. Users can explore the current year and future year scenario data, which sEEnergies project partners created in related work packages (1-3), as well as derived energy efficiency potentials and interrelations between sectors. Navigation on the map, the download of selected map content, and the sharing of maps in social media comprise central aspects of Peta usability, as partly illustrated in Figure 1.

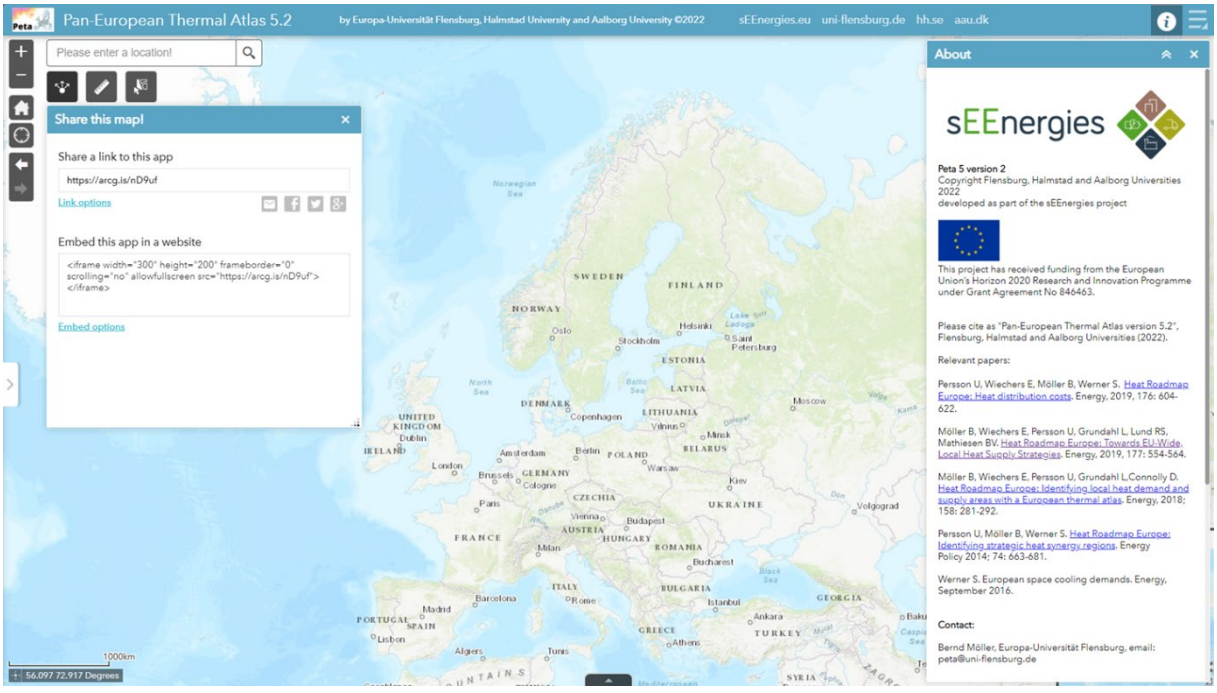

Figure 1. Screenshot of the Peta 5.2 web map application with activated social media sharing functionality (at left) and an "About" section with metadata and references (at right).

The web mapping application of the fifth version (associated to the sEEnergies project) was first published in 2020 as Peta 5.0.1, which containing a first set of layers, as described in the project report D5.3 (Möller, Wiechers, Persson, Nielsen, & Moreno, 2020). It included data related to base year energy demands and some first, intermediate, project results on energy efficiency potentials. Like in

earlier versions of Peta, layers from other projects (like e.g., Heat Roadmap Europe (HRE, 2018) and ReUseHeat (ReUseHeat, 2018)) were integrated into the application. In 2021, Peta 5.0.1 was eventually updated to the official version 5.1, with the publication of additional layers to complete the collection of base year data.

With the update to the current version 5.2, Peta has been complemented with layers from the sector-specific scenarios studied in different sEEnergies tasks (completed after the launch of Peta 5.1). The future scenario-based energy demands have been the primary inputs for mapping energy efficiency potentials in the sectors. They also form the basis for the modelling of district heating grid investment costs for 2050. By combining heat demands and heat supply in local supply districts, moreover, supply strategies can be explored on the map.

Besides sectoral demand data and energy efficiency potentials, Peta 5.2 also presents spatially evaluated energy efficiency potentials by means of the sEEnergies index (a concept introduced in the sEEnergies project and further explained in the parallel project report D5.7 (Möller, Wiechers, Sánchez-García, & Persson, 2022)). This index combines efficiency potentials by sector and technologies by use of a common grading and weighting scheme known from multi-criteria modelling.

The present report describes the main outcomes of the sEEnergies project deliverable defined as D5.5: 2nd set of map layers (future years scenarios for 2030 and 2050). Peta 5.2 focuses on the year 2050 to keep the content clearly arranged and manageable, but still includes 2030 data. This approach follows the focus of the energy system analysis in the sEEnergies project. Nevertheless, the Baseline 2030 heat demand density raster is available at the Open Data Hub.

1.2 How to read this report

This report is a supplement to the D5.3 report (Möller et al., 2020), which already describes the web mapping environment (see further also section 1.3 below). Therefore, the report at hand focuses on the changes in Peta 5 between version 5.1 and 5.2 (further described in chapter 2). As stated above, please note that a preliminary version of Peta 5 (version 5.0.1) was created in association with the D5.3 submission in late 2020. This web mapping application was later supplemented during 2021 and renamed “Peta 5.1”. Detailed information about the updated and additional datasets, including the underlying methods and assumptions, can be found in (Möller et al., 2022).

Here, it is further important to underline that the main deliverable material associated with this deliverable (D5.5), is in fact not the present report, but in essence the online web map itself and the context, functionalities, and numerous associated web map layers that it contains. Hence, the sole purpose of this report is to provide a brief introduction and description of the online web map.

Chapter 1 explains the context and the objectives of Peta 5 and the present report. Afterwards, chapter 2 presents the changes in Peta 5 from its first set of layers (Peta 5.1) towards the contents of the second update, i.e. the second set of layers which has come with the update to Peta 5.2. Finally, a short conclusion is given in chapter 3.

Abbreviations used in the present report reflect the use of acronyms in the online map, where limited space requires them. It may be advantageous to read the report while browsing the online map (see also Acronyms & Abbreviations, as well as Table 1, Table 2 and Table 3 below).

1.3 Online mapping as an output from the sEEnergies Project

The present deliverable of the sEEnergies project includes the production of a second set of map layers, based on sEEnergies future scenarios, for the web mapping application Peta 5. This online map disseminates those findings of the research, which are of geographical nature. The online map can be used to get a better understanding of the geography of energy efficiency and the synergies across sectoral divides for given locations. By assembling data from several sectors and phenomena, the online map generally supports comparisons and first-order assessments of local, regional, and national, level energy efficiency potentials for the current EU member states plus the United Kingdom.

The online map can further be used for consistency checks and illustrations in the various work packages in the sEEnergies project. While the geospatial data contained in Peta 5.2 forms input to the energy systems analyses in WP6, this has in some instances necessitated an aggregation to national levels. However, the local aspects of energy efficiency, which determine the potentials at national scales, can be visualized in Peta. In particular, the distribution of future heat demands, and the resulting district heating potentials and costs, can be studied by WP4 and WP6. WP1 may receive feedback on the distribution of building stock and energy efficiency, while WP2 and WP3 may have a closer look at potential synergies to other sectors.

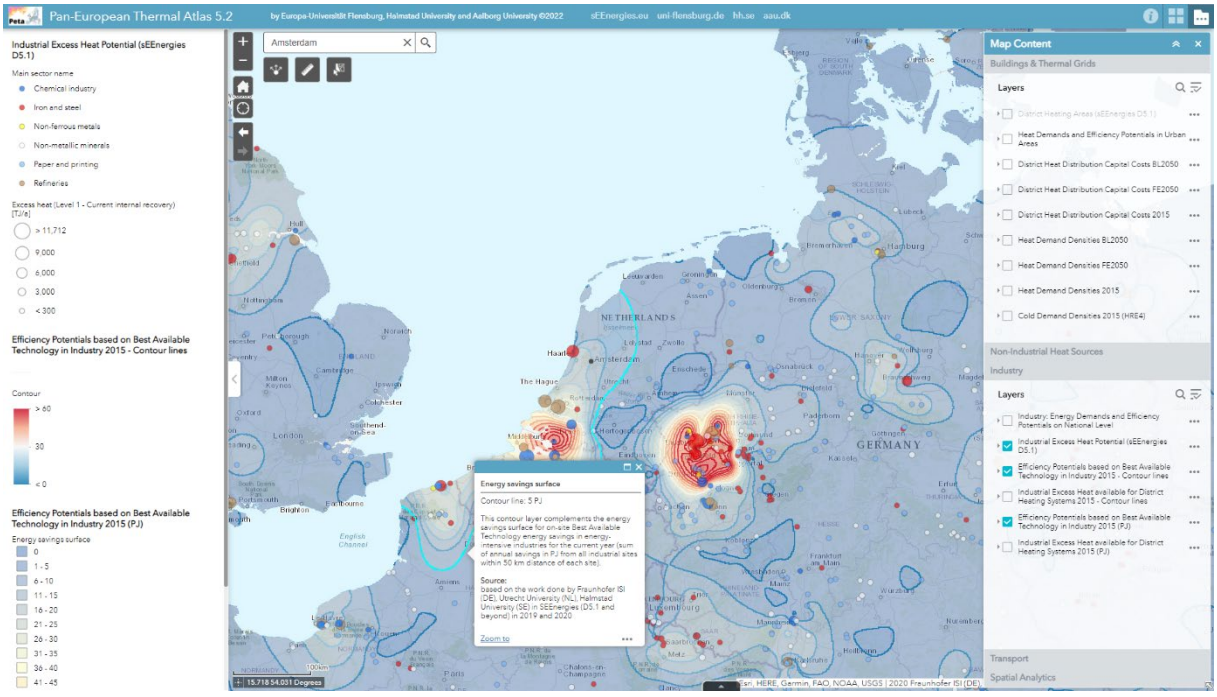

Figure 2. Screenshot from Peta 5.2 illustrating map layers related to energy efficiency potentials in the industry sector, in this case an energy efficiency surface layer, based on contour lines, that delineate total energy saving potentials within 50-km distances of existing industrial sites possible by introducing on-site Best Available Technologies (BAT).

Figure 2 provides an example screenshot from Peta 5.2 related to energy efficiency potentials in the industry sector (WP2), in this case with an energy efficiency surface layer, based on contour lines, that delineate the total energy saving potentials within 50-km distances of existing industrial sites possible to obtain by introducing on-site Best Available Technologies (BAT) under base year settings. On the right-hand side in Figure 2 may be seen the layer groups and their respective individual layers, which

can be accessed by a click on the folder symbol in the upper right corner. The panel on the left-hand side contains the legends of the selected active layers. Descriptive data contained in the layer is provided by pop-ups, which can be opened with a click on a layer element like a point, a line, or a polygon. Moreover, users can search places and measure distances. Elements of the atlas can be selected and exported in tabular format, and map views can be shared via links and in social media.

Datasets presented in Peta can be used through ArcGIS Online and downloaded from the sEEnergies Open Data Hub (sEEnergies Open Data Hub, 2020). Complementary to Peta 5.2, the sEEnergies mapping team has also developed a series of Story Maps, which, by combined use of text, maps, and diagrams, explains the sectoral energy efficiency potentials identified in the sEEnergies project (sEEnergies mapping team, 2022), as illustrated by the Story Map collection welcome page shown in Figure 3.

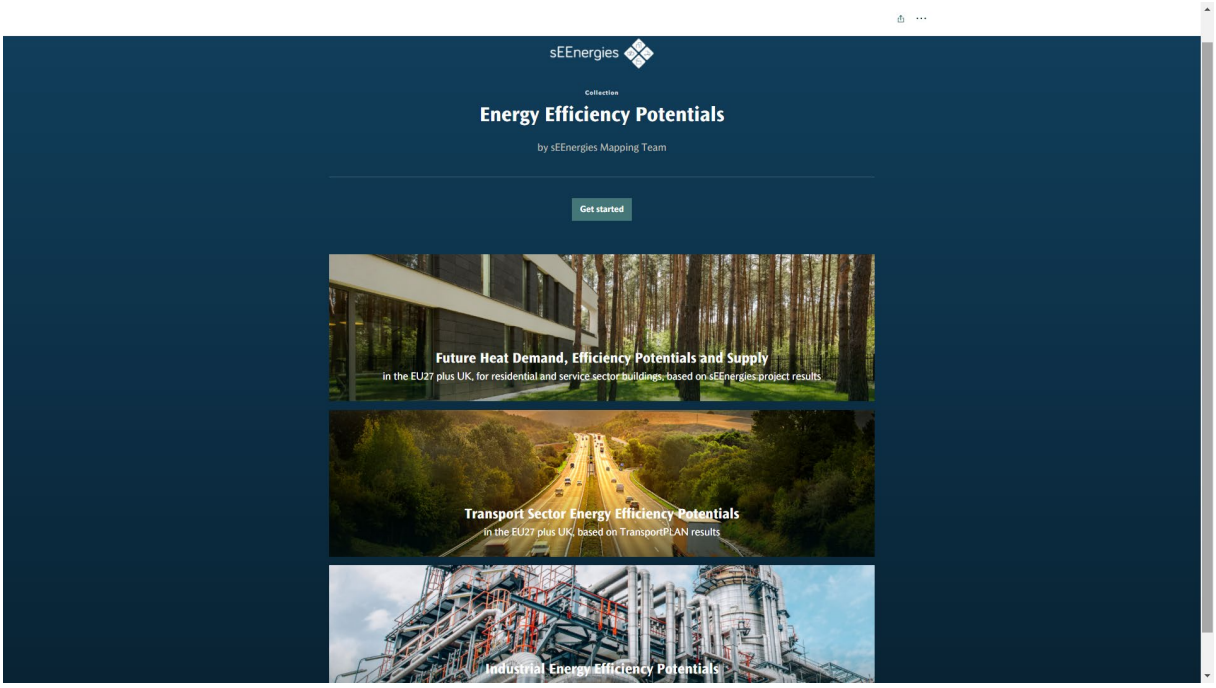

Figure 3. Screenshot of the sEEnergies Story Map welcome page. Three separate Story Maps are included in the current collection of Energy Efficiency Potentials: 1. Future Heat Demand, Efficiency Potentials and Supply; 2. Transport Sector Energy Efficiency Potentials; and 3. Industrial Energy Efficiency Potentials.

2 Updating the Pan-European Thermal Atlas to version 5.2

For the update of the Pan-European Thermal Atlas from version 5.1 to version 5.2, additional content was added to the original 5.1 version (see section 2.3 for further information). Consequently, its name was changed to "Peta 5.2". This means that the same URL is used, keeping all earlier project references to Peta 5 valid.

As for the original content of the 5.1 version, some layers (see further section 2.2 below) have been replaced in the updating process. They are therefore no longer available in the updated version. For the most part, however, all relevant original material in the 5.1 version is still present in the updated 5.2 version. In the following sections, these changes are tabulated.

2.1 Changes and additions to the online web map application itself

The web mapping application itself stayed almost unchanged. Only the welcome screen was updated and one additional layer group, for Spatial Analytics results, was added (as presented in Table 3 below).

2.2 Changes of existing content

In the process of extending the temporal coverage of Peta 5 to include future year scenario data, several layers have been updated. While many of the layers that describe the base year remain unchanged, several others were updated to include newer data from sEEnergies and other projects.

A major change is the replacement of Prospective Supply Districts (PSD) for the delineation of likely future district heat supply areas with the Urban Areas developed for D5.2 (Wiechers et al., 2020). This ensures consistency between layers describing several sectors, and results in a consistent mapping. Also, in contrast to Peta 5.1, the Peta 5.2 does not provide separate layers with renewable heat potential from biomass (S2Biom, 2016, 2022), solar (World Bank Group, ESMAP, & Solargis, 2022) or geothermal heat (GeoDH, 2014) sources. Rather, these heat sources have been integrated into the allocation to Urban Areas (see Table 3) in order to keep map content manageable.

Table 1 gives an overview of the layers which have been part of Peta 5.1, and the corresponding version available in Peta 5.1. References to the reports in which more detailed information can be found are given.

Table 1: Overview of Peta 5.1 layers and their status in Peta 5.2

Layer *or* **Group**	**Version available in Peta 5.2**
Buildings & Thermal Grids	
Cold Demand densities 2015	Peta 4.3 / HRE4 project: D6.5 report (Möller & Persson, 2018; Peta 4.3, 2018)
Heat Demand Densities 2015	Peta 5.0.1 / sEEnergies D5.3 layer based on HRE4 (not updated with sEEnergies data). On the Open Data Hub, the Baseline 2015 tiff file based on the sEEnergies (work package 1) data and using D5.7 heat distribution methods can be downloaded.

Buildings: Heat Demands and Efficiency Potentials (in Urban Areas)	Peta 5.2 / sEEnergies D5.7 layer showing aggregated scenario-specific Heat Demands and Energy Efficiency Potentials by Urban Areas. It replaces the Peta 5.1 layer which was based on sEEnergies WP1 data and D4.5 methods, and used NUTS3 boundaries.
District Heating Distribution Capital Costs 2015 (DHDCC)	Peta 5.0.1 / sEEnergies D5.3 layer based on HRE4 (not updated with sEEnergies data)
Current District Heating Systems (DHS)	Peta 5.0.1 / sEEnergies D5.1 layer based on HRE4 (not updated with sEEnergies heat demand data)
(Prospective Supply Districts (PSDs))	Peta 5.0.1 / sEEnergies layer based on HRE4 (not updated with sEEnergies data): **Discontinued** to the benefit of a layer with Urban Areas, but still available on the Open Data Hub.
Non-Industrial Heat Sources	
(Geothermal heat)	GeoDH project based Peta 4.3 / HRE4 layer (GeoDH, 2014): **Not available** in Peta 5.2, replaced by Urban Area layer with heat sources.
(Biomass Resources)	Biomass layer **was removed.** Biomass resources based on the S2Biom (S2Biom, 2016, 2022) project were associated to Urban Areas.
Excess Heat of Wastewater Treatment	ReUseHeat project layer was associated to Urban Areas (Persson, Averfalk, Nielsen, & Moreno, 2020)
(Excess Heat of Metro Stations)	ReUseHeat project layer is not available in Peta 5.2 yet; an updated version might become available during the spring/summer 2022.
Non-industrial, conventional Excess Heat Activities	As in Peta 5.1; HRE4 layer excluding industrial excess heat activities
Industry	
Industrial Excess Heat Potential	Peta 5.0.1 / sEEnergies D5.3
Efficiency Potentials based on Best Available Technology in Industry 2015 - Contour lines	Peta 5.0.1 / sEEnergies D5.3
Efficiency Potentials based on Best Available Technology in Industry 2015	Peta 5.0.1 / sEEnergies D5.3
Industrial Excess Heat available for District Heating Systems 2015 - Contour lines	Peta 5.0.1 / sEEnergies D5.3
Industrial Excess Heat available for District Heating Systems 2015	Peta 5.0.1 / sEEnergies D5.3

Transport Sector	
Cycling: Urban Area characterization	Peta 5.0.1 / sEEnergies D5.3
E-Roads Scenario #: points	Peta 5.2 / D2.3 Scenario 2e replaces scenarios 1 – 5 from sEEnergies D5.3 (datasets are still available for download on the Open Data Hub)
E-Roads Scenario #: routes	Peta 5.2 / D2.3 Scenario 2e replaces scenarios 1 – 5 from sEEnergies D5.3 (datasets are still available for download on the Open Data Hub)
E-Roads Scenario #: buffers	Peta 5.2 / D2.3 Scenario 2e replaces scenarios 1 – 5 from sEEnergies D5.3 (datasets are still available for download on the Open Data Hub)

2.3 Additional layers available in Peta 5.2

Peta 5.1 already contained layers describing energy efficiency potentials such as the potentials to develop district heating, utilize excess heat, or electrify transport (as outlined in Table 1). Nevertheless, the update to version 5.2 adds layers of sector-specific scenarios of future years, which have been finalised in parallel work packages of the sEEnergies project (work packages 1 – 3) after the launch of Peta 5.0.1/Peta 5.1 with its first set of layers. Table 2 provides an overview of new layers added to Peta 5.2.

Table 2. Overview of additional layers in Peta 5.2

Buildings	**Industry**	**Transport**
Heat demand grid, 1 ha: • Frozen Efficiency 2050 • Baseline 2015, 2030, 2050	Fuel, electricity and hydrogen demands: • 2015 and Frozen Efficiency for 2030 and 2050 • High energy efficiency scenario electrification and hydrogen fuel shift for 2030 and 2050 (100% Renewable Energies)	Transport demand and its drivers by mode, resulting fuel demands: • 2017 and Baseline 2050 with traditional urban development • Baseline 2050 with energy efficient urban development • Electrification+ scenario 2050 with energy efficient urban development
Based on sEEnergies work package 1	Based on sEEnergies work package 3 using IndustryPLAN	Based on sEEnergies work package 2 using TransportPLAN (see also D2.3)

The allocation of available and identified renewable heat resources, as well as of assessed potentials for excess heat recovery from industries, to Urban Areas, has been performed by means of least cost, network-based, allocation methods (for more in-depth accounts of the used approaches, see (Möller et al., 2022)). The use of Urban Areas as a base-entity for the assessment, quantification, and geographical positioning, of local energy efficiency potentials is exemplified in the Peat 5.2 screenshot presented in Figure 4. The allocation of industrial excess to potential district heating grids supplying residential and service-sector buildings, in particular, is a good example of cross-sector synergies assessed by geospatial analysis.

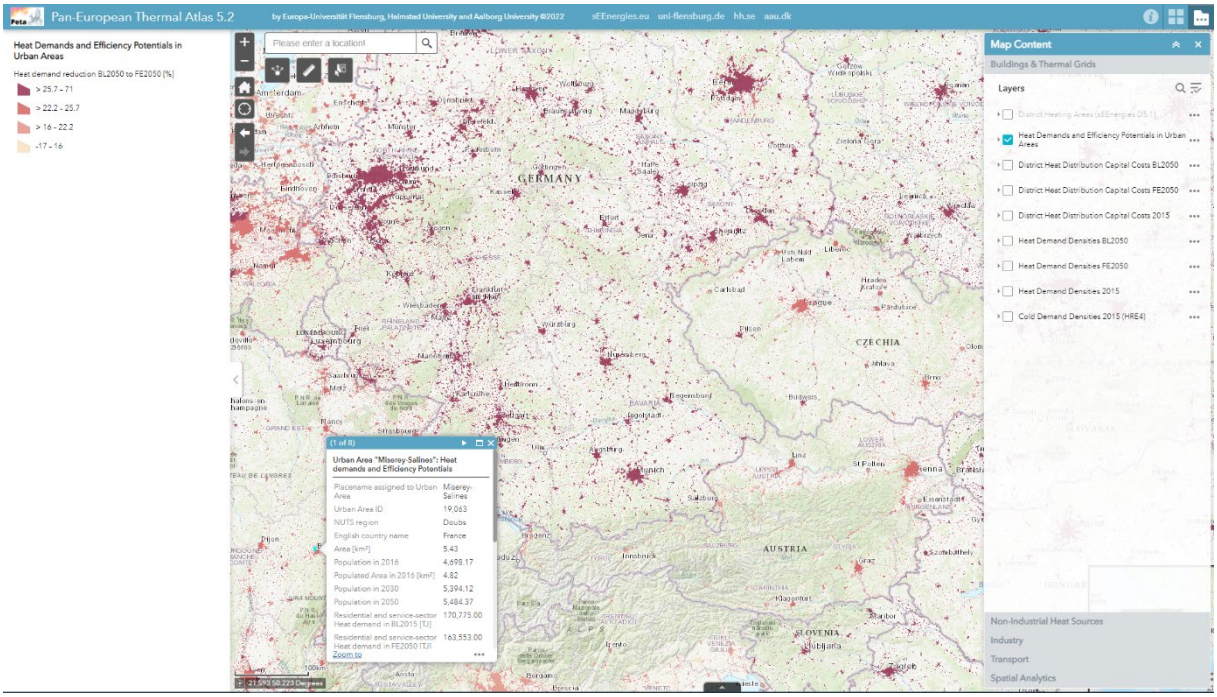

Figure 4. Screenshot from Peta 5.2 illustrating map layers related to energy efficiency potentials in the building sector, in this case showing heat demands and potentials related to mapped Urban Areas (UA).

The sectoral energy efficiency potentials were spatially processed and combined in the common sEEnergies Index, using the multi-criteria analysis method. This method allows for the creation of sector-specific indices and of a combination on the local level of Urban Areas. In addition, summaries of local index figures to national scales were generated. Table 3 gives an overview of newly added layers to Peat 5.2 which contain future energy demands and energy efficiency potentials, which have had a direct influence on the Spatial Analytics results. All details regarding underlying assumptions and methods are described in the D5.7 report (Möller et al., 2022).

Table 3: Detail of additional layers in the new layer group for Spatial Analytics results

Buildings & Thermal Grids
Future heat demand density grids for Baseline (BL) 2050 and Frozen Efficiency scenario (FE) 2050
District heating Distribution Capital Costs (DHDCC) for BL2050 and FE2050 (including both distribution and service pipes)
Non-Industrial Heat Sources (no additional layers)

Industry
Industry: Energy Demands and Efficiency Potentials on National Level
Transport sector
Transport: Energy Demands and Efficiency Potentials on National Level
Spatial Analytics
Local District Heating Potentials in Urban Areas
Available Renewable Heat Sources and Allocation of Excess Heat to Urban Areas
sEEnergies Index for Urban Areas (sector-specific input indices and result)

The Urban Areas, which themselves were developed as part of the earlier D5.2 outputs in the sEEnergies project (Wiechers et al., 2020), are also used to express local transport sector energy efficiency potentials, which is illustrated in Figure 5. In the capacity of local base-entities, the Urban Areas constitute the geographical dimension by which the sEEnergies Index is formulated. Hereby, spatially evaluated energy efficiency potentials from several sectors and infrastructures, may be combined in one, single metric which indicates – at the very local level – the total energy efficiency potential given the influence of genuinely local conditions and highly diverse unique circumstances throughout the European continent.

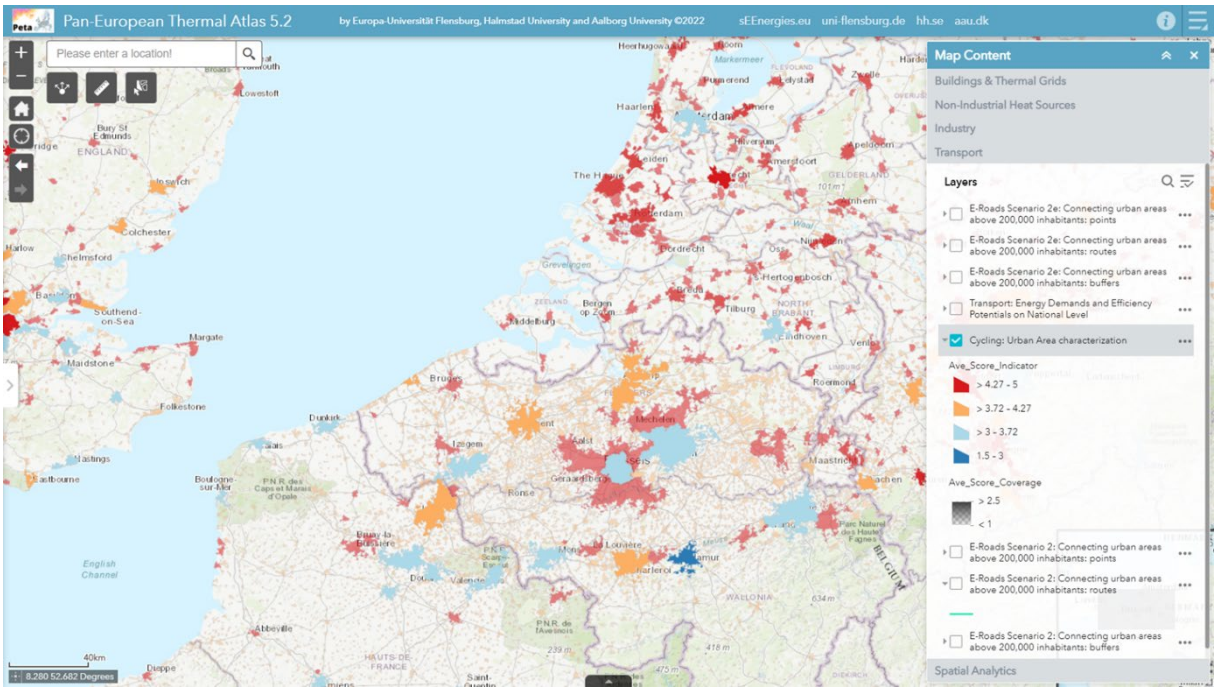

Figure 5. Screenshot from Peta 5.2 illustrating map layers related to energy efficiency potentials in the transport sector, in this case showing average score indicators for cycling potentials by respective mapped Urban Areas (UA).

3 Conclusions

The Peta 5 web mapping application, recognised by two updates in association to the sEEnergies project (Peta 5.1 and Peta 5.2), has been extended to include layers describing the future formulated in baseline and energy efficiency scenarios, for:

- Future heat demands in residential and service sector buildings
- Industrial plants
- Passenger and freight transportation, and
- Investment costs for future district heating systems (exemplified in Figure 6).

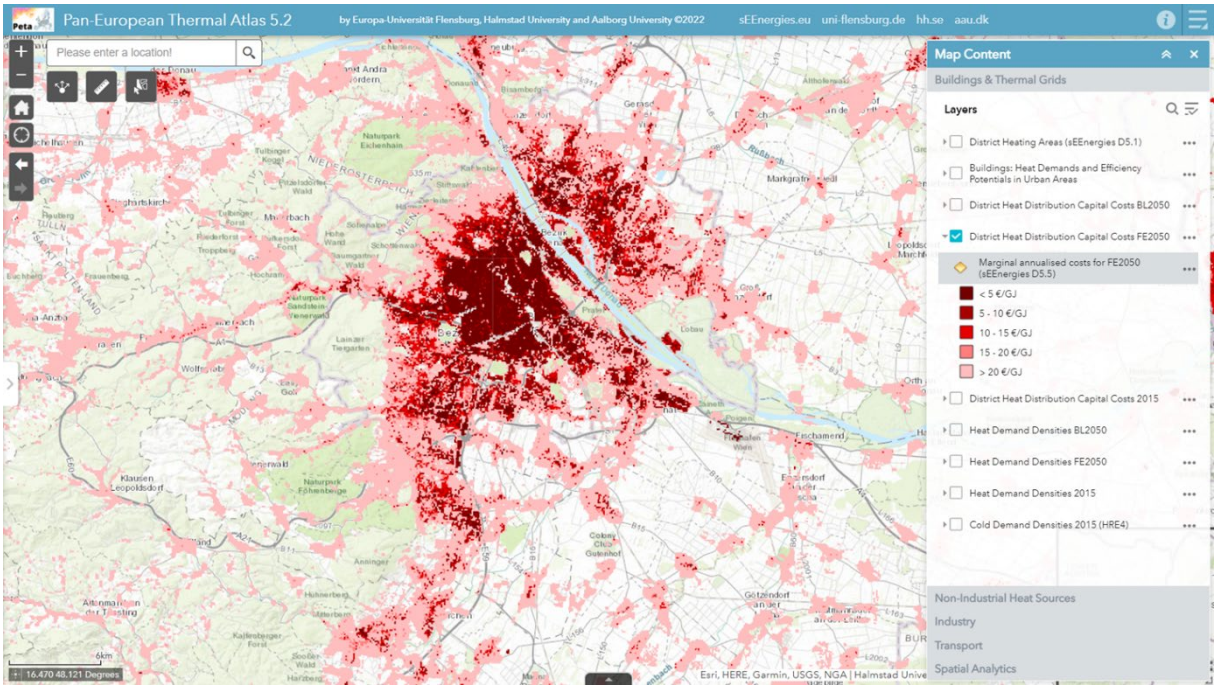

Figure 6. Screenshot from Peta 5.2 illustrating a map layers with marginal annualised investment costs for district heating by 1-hectare level resolution, in this case exemplified for the Austrian capital Vienna under the Frozen Efficiency 2050 (FE2050) scenario.

At the same time, energy efficiency potentials have been quantified and visualised (see for example Figure 4). Moreover, layers based on spatial analyses have been added, which show:

- Local District Heating Potentials in Urban Areas
- Allocations of renewable and excess heat to Urban Areas
- Compound energy efficiency potentials of Urban Areas (sEEnergies Index).

Datasets can be downloaded in the web mapping application (Peta 5.2, 2022) and through the sEEnergies Open Data Hub (sEEnergies Open Data Hub, 2020), which provides additional documentation. Story Maps add an additional dimension to the dissemination of the project results (sEEnergies mapping team, 2022). The Story Maps describe the energy efficiency layers and their interpretation in more detail. Documentation reports are available on the Zenodo site of the sEEnergies project (Zenodo sEEnergies, 2021). Most importantly, the D5.7 report describing the methodologies behind the datasets presented in this report (Möller et al., 2022).

4 References

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This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 846463.