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Background report providing guidance on tools and methods for the preparation of public heat maps

M. Jakubcionis

K. Kavvadias

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Abstract
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This methodology is intended to provide guidance to MS on the structure and methods of preparation of a map of the national territory, identifying heating and cooling demand points, district heating and cooling infrastructure and potential heating and cooling supply points.

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List of abbreviations and definitions

CA	comprehensive assessment of national heating and cooling potentials;
CSWD	Commission Staff Working Document;
DHC	district heating and cooling;
CHP	Combined heat and power;
EED	Energy Efficiency Directive;
GIS	geographical information system;
MS	member states;

Preamble

This methodology is intended to provide guidance to MS on the structure and methods of preparation of a map of the national territory, identifying heating and cooling demand points, district heating and cooling infrastructure and potential heating and cooling supply points.

Since there are many diverse methods and tools that can be used for processing of the data, making of the map and eventual publishing, this methodology is not intended to cover them all but instead should be viewed as a supporting document and a source of ideas.

1 Introduction and current experience

The Energy Efficiency Directive (EED) [1] states in Annex VII (1) that the comprehensive assessment of national heating and cooling potentials shall include a map of the national territory, identifying heating and cooling demand points, existing and planned district heating and cooling infrastructure and potential heating and cooling supply points.

Some MSs have already published national territory heat maps that fulfil similar purposes, i.e. visually representing geographical relationships between different elements of heat consumption and supply systems. These can potentially be reused, but it has to be verified that the information contained in those maps meets the requirements of the EED and of the CA. Those maps can be complemented by adding new layers of information.

In the literature, a heat map does not necessarily refer to an actual map. In some cases it refers to a data matrix which consists of a rectangular tiling with each tile shaded on a colour scale to represent the value of the corresponding element of the data matrix. However, in the context of the EED, it refers to an illustration of values on a geographical basemap, in a similar way as a thermometer shows the temperature on a quantitative colour scale. More specifically such heat map is defined as the map of national territory containing information about different components of heating and cooling infrastructure. In other words it is the visual representation of the energy demand/supply and the data collected and pre-processed at the first stage of the Comprehensive Assessment described in Art. 14(1). It has to be noticed that a heat map does not contain exclusively information about heating.

The actual process of preparing the national territory heat map can be divided into the following steps which will be analysed throughout this report:

- Collection of necessary data;
- Selection of appropriate tools for data processing and composition of the map;
- Organising, adding and post-processing collected data into the map;
- Deployment of the map on the web for the public access.

1.1 Current experience

Countries without existing heat maps nor experience in preparing heat maps may consult reports on heat mapping produced by other MS in order to get a first impression of its features. For instance the methodology report of Scottish Government is accessible together with a functioning

interactive heat maps on a dedicated web site[1]. The National Heat Map of England[2] or Heat Atlas of Netherlands[3] are other examples that can be consulted. However, be aware that existing heat maps do not necessarily meet all the requirements of the EED and the Commission Staff Working Document (CSWD) [2] in regard of technologies and details to be included into it.

As an example, a piece of the Heat Atlas of the Netherlands is presented in Figure 1. In this figure the annual consumption of heat in the different neighbourhoods in and around the city of Alkmaar is presented. Different colouring intensity represents different amounts of heat consumed in particular neighbourhoods.

Figure 1. A view of Heat Atlas of Netherlands[3]

Figure 2 presents a view of UK national heat map. Some basic components can be seen such as the selection of visible layers, legend, zooming/panning operation and other reporting options. The heat demand is presented as continuous contours.

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[1] www.scotland.gov.uk/heatmap

[2] http://tools.decc.gov.uk/nationalheatmap/

[3] http://agentschapnl.kaartenbalie.nl/gisviewer/viewer.do?code=0f2d31b5cee824a43bf2ad238f41d101

Figure 2. UK national heat map

There is a lot of experience in heat mapping of renewable resources that can be used for the preparation of heat map envisaged by the EED. Since the availability of solar, wind, geothermal and bioenergy resources are dependent on the location, for reasons that are related to the nature of the technology, maps have been developed and used in many studies such as potential analysis, or techno-economic studies of individual installations. Some of them have been made publicly available. Typical examples of such maps are the Photovoltaic Geographical Information System (PVGIS)[4] developed by JRC or the European geothermal atlas.[5] A national view of such heat maps can be incorporated as extra layer in the heat map prepared under the EED (see Section 6).

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[4] http://re.jrc.ec.europa.eu/pvgis/

[5] Suzanne Hurter, Rüdiger Schellschmidt, (2003) Atlas of geothermal resources in Europe, Geothermics, Volume 32, Issues 4–6, pages 779-787

2 Data collection for the purpose of heat map composition

All data collected should always have a spatial dimension, i.e. it has to be linked with a location. Depending on the data type, and information available, this location can be a single building, a base heat demand area, some administrative boundaries or even a whole region. As a first step, the information can be organized in databases or in tabular forms adding an extra column containing a identifier or what is known from databases as a 'unique key' that will relate this information with a location/area. It is advised that such unique keys should match the system identification system used by the statistical organization of the country or other main sources of descriptive information, e.g. the numerical codes, postal codes, names. This will allow visualizing the information to a location when the heat map is prepared.

A large part of the input data required for preparing the heat map are also required to complete other parts of the CA as discussed in Deliverable 1, Chapter 1 of this methodology. However, not all the information, which is crucial for the other parts of the CA, can be placed in heat maps or is necessary for its completeness.

In the following section the particularities of mapping of different sectors are discussed.

2.1 Data on energy consumers

The Energy Efficiency Directive (EED) [1] Annex VIII (1)(c)(i) states, that the map of the territory of a country should include information on heating and cooling demand points, including:

a) municipalities and conurbations with a plot ratio of at least 0.3;

b) industrial zones with a total annual heating and cooling consumption of more than 20 GWh.

The following sub-sections present an overview of information which should be gathered and incorporated into the heat map for these categories of heating and cooling consumers.

2.1.1 Municipalities and conurbations

Municipalities and conurbations are to be represented in the map as a heat demand territories and not as a points. As such, they are populated by distributed energy consumers, such as residential and service sector buildings.

An essential step of the CA is to divide the municipalities and conurbations of a MS territory into properly sized pieces, which will be further referred to as *base heat demand areas*. This is necessary in order to ensure high enough scale and resolution of the heat map as well as to make a correct calculation of plot ratios as described in the following paragraphs.

The issues of choosing properly sized base heat demand areas have been discussed in Subsection 1.3.2 of Deliverable 1. It is suggested to use the smallest territorial units of a country for which reliable data on population count can be established as a base heat demand areas. In some countries these are referred to as postcode districts or neighbourhoods. Spatial information about the base heat demand areas is also required.

The EED suggests that the plot ratio should be used as a threshold for inclusion of heat demand areas into the heat map. The plot ratio is a factor used to identify the feasibility of installing district heating systems in a given area. It is defined as the ratio of useful (heated) floor area of buildings to the land area where the buildings are situated:

$$Plot\ ratio = \frac{Useful\ floor\ area\ of\ buildings, m^2}{Land\ area\ of\ territory\ where\ buildings\ are\ situated, m^2} \qquad (1)$$

The denominator of this equation includes not only land area beneath the buildings but also the area of empty land between the buildings.

Plot ratio of 0.3 can be used as a threshold making the decision whether particular base heat demand area should be represented in the map, as recommended in EED Annex VIII. However, a map of the national territory can potentially include all base heat demand areas thereby allowing the user to choose which base heat demand areas to be displayed. For instance, if one wants to analyse areas with plot ratio higher than 0.2, these could be displayed in the heat map.

In order to estimate plot ratios of base heat demand areas, actual data about areas of buildings located in each area can be gathered from relevant databases. An alternative approach would be to gather data about population count and land area of each base heat demand area as well as average heated floor area of buildings per capita. Possible sources of such information are discussed in Subsection 1.3.2 of Deliverable 1, together with other methods for plot ratio estimation. This data will be then combined and a plot ratio of each base residential heat demand area can be calculated.

If available, more detailed information can be included into the map for each base heat demand area since it will enhance the usefulness of the heat map. For instance, information about different segments of residential buildings, such as single-family houses, terraced house and multi-family apartment buildings present in in each base heat demand area can be included.

Since these building types are characterized by different relative annual consumption of heat (kWh/m²·a) information about heat densities of different base residential heat demand areas can be deducted.

In case detailed energy performance of different segments of residential buildings are unavailable, heating and cooling consumption can be established using alternative methods, as described in Subsection 1.3.2 of Deliverable 1.

Additional information that can be added to the heat map, which will be needed for the CBA analyses of this methodology, is the sort of heating and cooling used by residential energy consumers at present. Fuels and technologies used in a given base heat demand area can be represented in percentages. Furthermore, such information might be represented for different segments of residential buildings of a particular base heat demand area. This information can be represented by using tables, pop-up windows or by making thematic maps.

Service sector buildings are also included into the map as constitutes of base heat demand areas and their heated area is added to heated area of residential buildings, located in particular heat demand area. Information about the segments of service buildings can be included into the map as additional information. The segmentation should be sufficient to reflect the distribution of buildings with significantly different energy consumption characteristics in a MS. For instance, service sector building stock might be sub-divided into:

- Government institutions/public buildings;
- Education institutions (nurseries, schools, universities and so on.);
- Hotels;
- Hospitals;
- Shopping centres and malls;
- Office buildings;
- Catering establishments;
- Prisons
- Other.

Information gathered might contain number of buildings of a particular sector, located in a given base heat demand area, their size, heating/cooling consumption and so on. Very large service sector consumers, such as hospitals, might be indicated as points in the map, but this should be treated as optional information, because they still would need to be accounted for as constitutes of base heat demand areas. To identify them as points would be particularly useful for example in the case that they are analysed as a locations for installation of local cogeneration units.

Similarly to residential buildings, information on the current methods of heating and cooling generation for different segments of service sector buildings might be included as additional

information. Fuels and technologies used in a given base heat demand area can be represented in percentages.

Possible sources of information on service sector heat consumers are discussed in Subsection 1.3.3 of Deliverable 1.

2.1.2 Industrial zones and agriculture

As a minimum, the heat map should contain information about industrial zones consuming more than 20 GWh of heating and cooling per year. Although not mentioned in Annex VIII of the EED, it would make sense, where relevant, to include information about agricultural heat consumers with heating and cooling consumption higher than the similar threshold requirement, since the CA should cover these consumers too. It can also be considered to include industrial heat consumers with heating and cooling consumption lower than the threshold, if more complete and accurate representation of heat demand is desired. In such a case a menu of the map could have an option to select different groups of industrial consumers based on their annual heating and cooling consumption.

Possible sources of information on industrial and agricultural heat consumers are discussed in Subsection 1.3.1 of Deliverable 1.

Information about each industrial and agricultural consumer might contain its geographical location, annual heating and cooling consumption, requirements for the quality of heat as well as the current method of heating and cooling provision. Since industrial zones and agricultural heat consumers are treated as demand points when included in the heat map, information about their location should contain their geographical coordinates (latitude and longitude).

Additional information, if available, may also be included. For instance, it might be indicated to which industrial segment (cement industry, pulp and paper, metallurgy, ceramics and so on) a particular industrial zone belongs. Sub-segmentation might be dependent on conditions of particular country or its region.

2.2 Data on existing and planned district heating and cooling infrastructure

As described in EED Annex VIII (1)(c)(ii), the map of the national territory should contain information about district heating and cooling infrastructures, both existing and planned. This information allows determining the most attractive opportunities for heat linking of heating and cooling demand areas to waste heat sources as well as a better estimating the costs for transporting heat. Additionally, it would help to visualize the potential for extension of existing district heating and

cooling networks as well as installation of new ones in areas of high heat demand (such as municipalities and conurbations with a plot ratio higher than 0.3) which currently are not covered by such networks.

Possible sources of information on existing and planned district heating and cooling infrastructure are discussed in Section 1.5 of Deliverable 1.

The data in the map should include the location of the district heating and/or cooling network and other related equipments. In order to avoid confusion, it does not have to include data on energy production installations supplying district heating and cooling networks since they should be covered in the energy production part, discussed in the next section.

In order to make the map as useful as possible, district heating and cooling networks should preferably be represented as areas (polygons). In such a way the extent of the pipeline coverage in given area would be visible.

Additional information about each district heating and cooling network might include:

1. Status of DHC network: operational or planned and the year of beginning of operation, either actual or planned.
2. Maximum/average demand in MW (for winter and summer seasons separately).
3. Annual heating and cooling quantities supplied to consumers, in GWh/a or equivalent units. If possible, it is advised to collect data on heating and cooling consumption for a period of time (3 years or more) and to display average numbers in the heat map. This data might be made visible to map users in the form of pop-up graphs when particular DHC network is selected.
4. Average annual heat losses of the network, GWh/a.

Additional information, which would ease comparison of energy efficiency of different district heating networks, might include average heat losses in % of total energy supplied into the DHC network. Again, changes of heat losses for some period of time (over several years) might be represented in the form of pop-up graphs. Such graphs would provide valuable additional information about changes in energy efficiency of particular DHC infrastructures. Furthermore, DHC networks, where heat losses are significantly increasing, decreasing or remain relatively constant (in comparison with the first year of data availability) might be indicated, for instance, with different colour or sign.

In case heat links (pipeline connections of waste heat sources with DHC networks over significant distance) already exist, they should also be indicated in the map. Information represented should include trajectory of the connecting pipeline, year of construction, diameter, and annual

transmission of heat. Location information should include coordinates of start and end points of the pipeline as well as coordinates of intermediate points in case the pipeline trajectory changes significantly.

2.3 Data on current and potential heating and cooling supply points

The EED Annex VIII (1)(c)(iii) specifies that the map should include information about potential heating and cooling supply points, including:

- electricity generation installations with total annual production of electricity exceeding 20 GWh;
- waste incineration plants;
- existing and planned cogeneration installations based on technologies listed in Part II of Annex I of EED;
- district heating installations, meaning producers of thermal energy supplying district heating networks;

Although not included into this list, it would make sense to include information about industrial installations that have the ability to supply waste heat into the heat map too. Also, other energy sources, such as renewables, should be added for completeness of the map.

Possible sources of information on potential heating and cooling supply points are discussed in Section 1.4 of Deliverable 1.

Information on potential heating and cooling supply points might include the following information:

1. Location of the potential supply point. Since potential heat sources are treated as points, their location should be defined by their geographical coordinates (latitude and longitude). Unique name of the plant or installation might also be included for easier identification of particular plant.

2. Type of potential supply point (waste incineration plant, electricity generation installation, etc.).

3. Fuel used. In case of dual or more fuel the percentages of different types of fuel consumed might be included.

4. Quantity of waste heat available. Section 1.4 of Deliverable 1 provides guidelines for the estimation of waste heat amount for industrial and other sources of heat.

5. Quality of waste heat available. It should be indicated what is the temperature of available waste heat. For instance, it might be indicated if waste heat available is suitable for district heating (depending on the type of DHC network and season, this might mean more temperature of more than 80–120 °C).

Additional information can be included into the map for potential heating and cooling supply points, i.e. attribution of a particular point to a particular subcategory of energy source. For instance, electricity generation installations can be subdivided into categories based on employed technologies, e.g. steam turbine, combined cycle, while cogeneration installations can be subdivided based on employed technologies, see list presented in Part II of Annex I of EED for more information.

3 Common tools and layers types

All heating and cooling demand (and supply) layers are a result of data analysis in an appropriate georeferenced format. The heat map itself should be organized into the layers each containing information about different aspects of heating and cooling consumption and supply, discussed in Sections 2.2, 2.3 and 2.4.

In this Section the most common tools for the preparation of the heat map layers are presented along with a comparison of the different layer types suitable for this analysis.

3.1 Tools for the creation of heat map layers

The heat map might be prepared using different methods and tools. It is advised to use geographical information system (GIS) software, in order to make the heat map preparation more efficient. GIS software can be used for accomplishing different tasks, for instance map creation, geospatial data compilation, analysis of mapped information, managing databases and so on.

There is a great variety of GIS software available, which meets different needs and preferences of its users. Proprietary GIS software as well as freeware and open source alternatives are available. One of the most widely used commercial GIS software is ArcGIS, produced by Environmental Systems Research Institute (ESRI). Other examples of commercial GIS software include MapInfo by Pitney Bowes Software, AutoCAD Map 3D by Autodesk, ERDGAS IMAGINE by ERDGAS Inc. and others.

There are also free and open source GIS applications such as QGIS (previously known as Quantum GIS), gvSIG, GRASS GIS or similar tools. The choice of GIS tool will depend on which features that are needed by the user.

In addition, a wide variety of web-based or web-deployed tools are available, enabling datasets to be analysed and mapped without the need for local GIS software installation. Such tools include Google Maps, Bing Maps, ArcGIS Online and others, but some of them might be more restricted in terms of usability.

3.2 Heat map layer types

Layer types created by GIS tools can be classified either based on their data type or on the level of detail as explained in the following sub-sections.

3.2.1 Classification based on data type

GIS layers can be classified according to their data storage type into the following two types: vector or raster. Geometrical objects such as streets, rivers or administrative boundaries can be

represented either by vector data (points, lines and polygons), or by raster data (grid of pixel-filled cells). Many GIS can handle vector and raster data to provide the advantage of both.

An example of the same data presented in both layers can be seen in Figure 3.
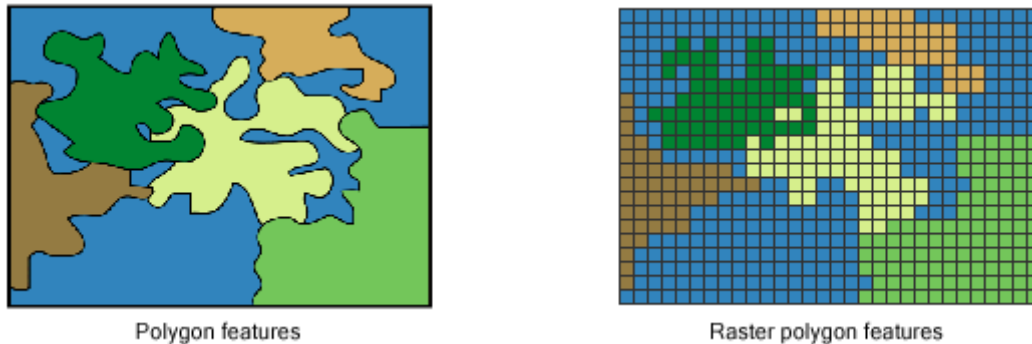

Polygon features   Raster polygon features

Figure 3 Vector versus raster features[6]

Vector layers.

In a vector layer the image is made up of points, lines or polygon, also known as features. Each feature of the layer is stored by using its coordinates. As a result that information is retained no matter how much you scale the image up and down because every time it is drawn from the coordinates.

Each vector layer can contain different features, such as municipalities, pipelines, different installations or other geographical features, which are represented in different ways and therefore they require different kind of geospatial data. In general, these features can be grouped into points, lines and areas.

- Points are represented by a single location and are defined by the pairs of coordinates, such as latitude and longitude. Examples of points in the heat map include industrial heat consumers and waste heat supply installations.

- Lines are defined by a sequence of points which are connected by lines. Examples of lines in the heat map might include heat linking pipelines or pipelines of DHC networks.

- Areas are defined by a sequence of points, connected by lines forming closed chain or loop, thus forming a polygon. Examples of areas or polygons in a heat map will include residential areas as well as DHC networks.

It is usually a good practice to group information of different types in different layers.

Example of different objects of a heat map is represented in Figure 4.

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[6] http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Representing_features_in_a_raster_dataset
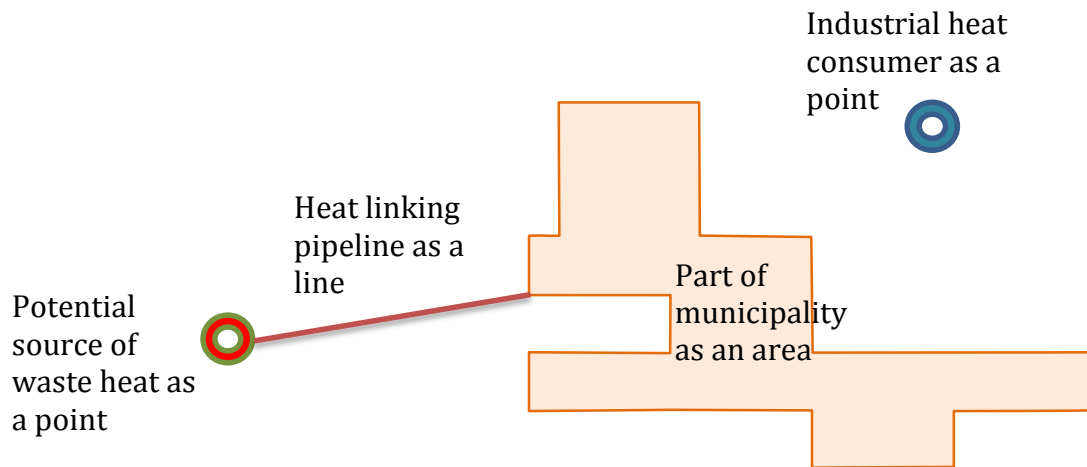
Figure 4. Example of different objects of the heat map.

Each feature of a GIS vector layer can be linked with other non-spatial (attribute) information, e.g. population contained in a specific polygon, or energy produced from a specific point. This information is often referred to as attributes that add depth to the map by displaying on demand additional information about a particular component of the map. Thus, in vector layers we usually find two kinds of information per feature: spatial (location) and non-spatial (descriptive), i.e. "where" and "what".

An example of vector layer attribute table, containing information of base heat demand areas, is presented in Table 1.

Table 1. Example of descriptive data table.

OBJECTID	PLOT_RATIO	YEAR	HEAT_CONS	COOL_CONS
001101	0.35	2014	2455	156
001102	0.33	2014	2314	147
001103	0.51	2014	3577	227
001201	0.45	2014	3156	200
001202	0.22	2014	1543	98

Each row of the data table is related to a single feature which in this case is a polygon (neighbourhood, city or municipality) and describes different properties of that location. The columns contain information about different attributes, such as plot ratio and consumption of heat for heating and cooling purposes.

The most common geospatial vector data file format is called *shapefile* (.shp), initially developed by ESRI as a (mostly) open specification for data interoperability among ESRI and other GIS software products.

Raster layers. These layers are actually georeferenced images. The main difference is that these layers are pixel based and not vector based. Each pixel (or cell) can hold only one value. The same information can be depicted in both formats, but the level of accuracy, storage size and analysis capabilities differ and define the most appropriate format for each occasion.

A critical parameter is the resolution i.e. the minimum cell size. The effect of the different resolutions when converting from a vector layer is illustrated in Figure 5. Most common file format for raster layers is georeferenced TIFF files (.tif). When selecting a resolution there is always a compromise between data accuracy and size required.
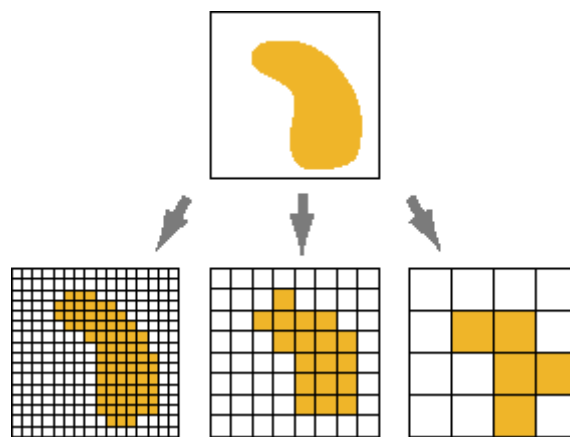

Figure 5. Raster layer in different resolutions.[7]

Most important advantages and disadvantages of the two layer types are presented in Table 2 [3]:

Table 2. Comparison of raster and vector layers.

	Vector	Raster
Advantages	1. Data can be represented at its original resolution and form without generalization. Graphic output is usually more aesthetically pleasing (traditional cartographic representation); 2. Since most data, e.g. hard copy	1. The geographic location of each cell is implied by its position in the cell matrix. Accordingly, other than an origin point, e.g. bottom left corner, no geographic coordinates are stored. 2. Due to the nature of the data storage technique data analysis is

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[7] http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=What_is_raster_data%3F

	maps, is in vector form no data conversion is required.	usually easy to program and quick to perform.
	3. Accurate geographic location of data is maintained.	3. The inherent nature of raster maps, e.g. one attribute maps, is ideally suited for mathematical modelling and quantitative analysis.
	4. Allows for efficient encoding of topology, and as a result more efficient operations that require topological information, e.g. proximity, network analysis.	4. Discrete data, e.g. forestry stands, is accommodated equally well as continuous data, e.g. elevation data, and facilitates the integrating of the two data types.
Disadvantages	1. The location of each vertex needs to be stored explicitly. 2. Algorithms for manipulative and analysis functions are complex and may be processing intensive. 3. Continuous data, such as energy demand data, is not effectively represented in vector form. 4. Spatial analysis and filtering within polygons is impossible.	1. The cell size determines the resolution at which the data is represented. 2. It is especially difficult to adequately represent linear features depending on the cell resolution. Accordingly, network linkages are difficult to establish. 3. Processing of associated attribute data may be cumbersome if large amounts of data exist. Raster maps inherently reflect only one attribute or characteristic for an area. 4. Since most input data is in vector form, data must undergo vector-to-raster conversion. Besides increased processing requirements this may introduce data integrity concerns due to generalization and choice of inappropriate cell size.

The two data types can be transformed into each other, although the conversion usually involves a certain loss of precision and information. Some operations for the analysis and the preparation of data described in the following paragraphs are only available in one of the two modes, so sometimes the conversion is unavoidable.

3.2.2 Classification based on level of detail

Layers can be classified according to their data granularity and detail on the following types:

- Choropleth map: Common examples of such maps are country/regional statistics (e.g. population). In these maps predefined areas based on known borders (e.g. countries, administrative regions) are shaded according to the level of a specific variable (e.g. energy demand, number of buildings etc.). Choropleth maps are usually depicted as vector layers due to small number of features needed to describe the data.
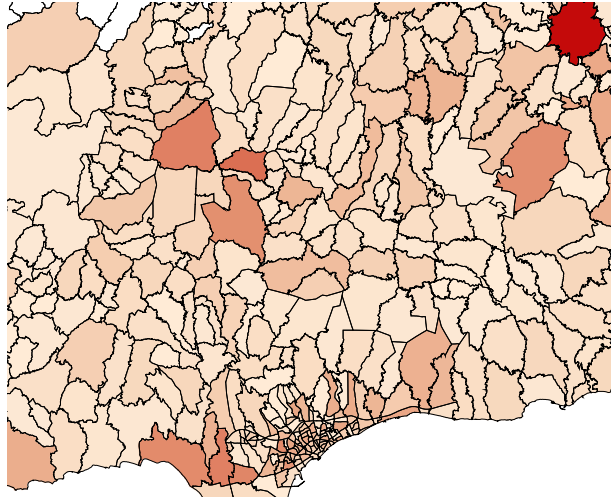

Figure 6 Example of a choropleth map

- Isopleth map: In these maps a variable is illustrated on a map as a continuous contour i.e. a surface that is projected in two dimensions. Areas with the same attribute create that contours have the same colour. Compared to the choropleth map this is a more realistic visualization of the variable since there is no abrupt change of the level of the variable between two regions. However, there are more data requirements for the preparation of such map, data usually collected in a specified grid resolution.

 A common example of such maps are the meteorological measurements such as temperature or barometric pressure. Each cell has a value which is either a real measurement or an interpolation of measurements of a larger-sized grid or even arbitrary points. Isopleth maps are usually stored as raster layers.
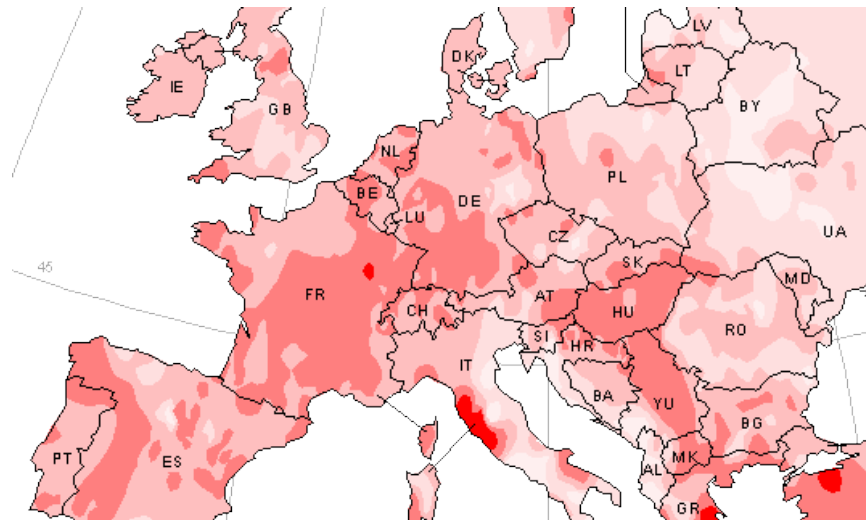
Figure 7 Example of isopleth map[8]

- Dasymetric maps are a relatively new technique that acts like a compromise between choropleth and isopleth maps. It is mainly used to improve the accuracy of choropleth maps by using ancillary data in order to spatially classify volumetric data (e.g. using land use classes to spatially classify energy intensity in a single region). A more detailed look in this technique is given in section 4.1

[8] Source: European Communities (2002), Atlas of Geothermal resources in europe http://www.geni.org/globalenergy/library/renewable-energy-resources/europe/Geothermal/Geothermal%20heat%20-%20Potential_files/6-1-100.gif

4 Best practices during heat map construction

Depending on the data availability and the results of the data collection procedure there can be two ways to organize the data:

1. Use detailed bottom – up data for all entities: e.g. information about all energy consumers including the type of consumer, and the energy spent for a specified timeframe (usually a year). This information usually exists if there is an organized metering system or methodology to create a centralized inventory of energy, such as a building cadastre.

2. Use statistics and indicators on the smallest geographical division available to describe the energy demand. A very popular methodology is the energy indicators decomposition as described by IEA and EC [4-6]. According to it, the energy demand of each can be decomposed along three main components:
   a. *activity* which is measured as population, floor area, economic output etc.
   b. *structure* which divides each sector into subsectors
   c. *energy intensity* which is energy use per unit of sub-sectoral activity.

In the first case a detailed vector map consisting of all entities can be compiled. It is a good practise for the heat map visualisation to smooth out the information represented by a collection of points in a way that is more visually pleasing and understandable; it is often easier to look at a raster with a stretched colour ramp than it is to look at individual groups of points, especially when the points cover up large areas of the map. Hence, these layers can be converted to isopleth raster for a more homogeneous visualization of the demand. This is usually done via the **Kernel Density** method (Figure 8), which converts a point vector to raster isopleth via interpolation of the points. For this conversion only the information of one variable (column) can be maintained i.e. energy demand/unit area.

In the second case, the information will be collected in a more aggregated form. This is usually an administrative level which is what is called a base heat demand area in D1. In this case the information will be presented as a choropleth map, where each area will have an aggregated value of demand.
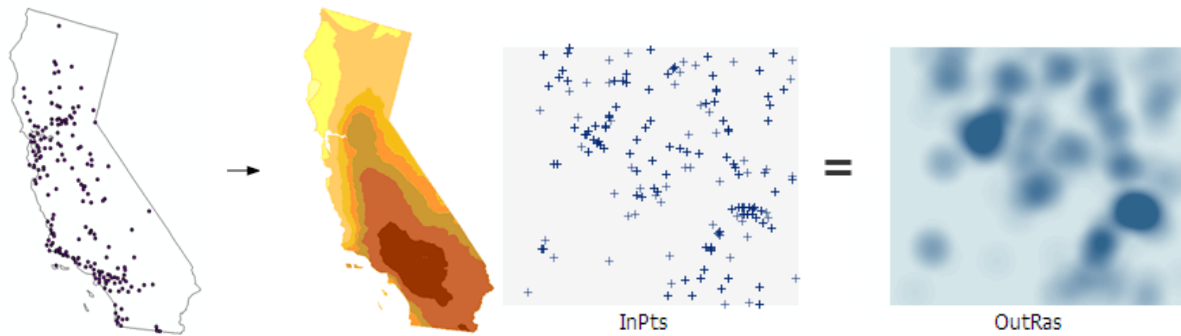
Figure 8. Concept of Kernel Density method[9].

It is usually recommended to use normalised maps because different areas are not equal in size and non-normalised maps can give a false impression. Figure 9 shows the same quantities (a) as an absolute number (TJ) and (b) normalized by the feature area (TJ/m^2). It can be seen that very small and very large areas differ significantly in these two approaches. The normalized map however allows a more accurate perception of the information.

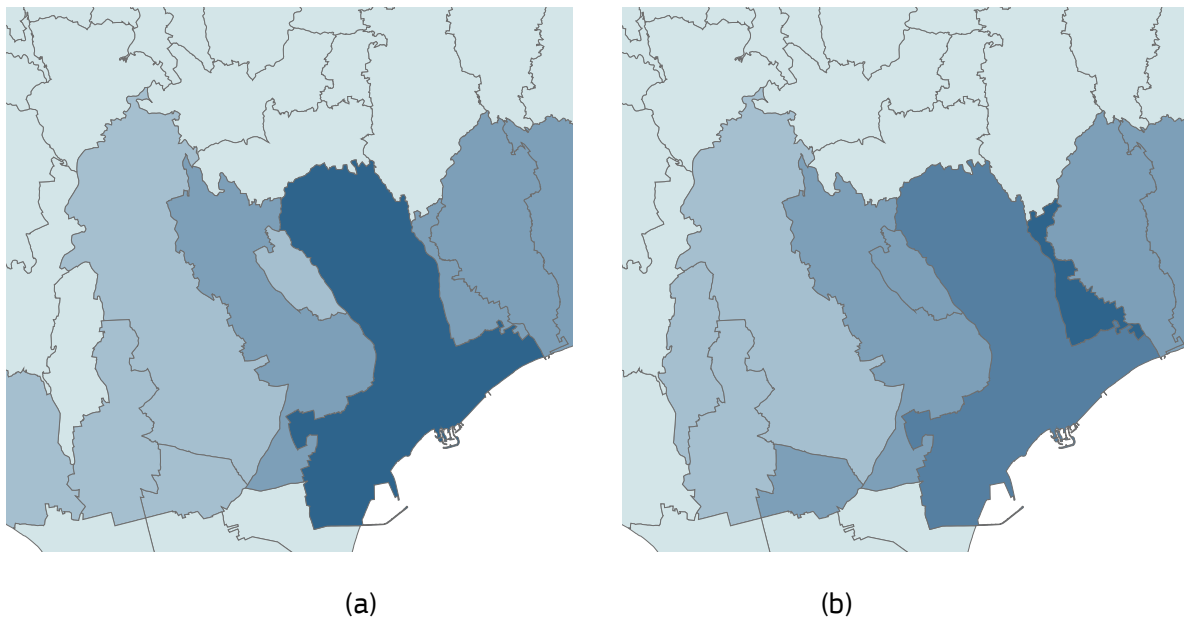(a)   (b)

Figure 9 Difference between non-normalized (a) and normalized (b) choropleth maps

The colour selection is very important in order to assure that the underlying data is communicated accurately. Data contained in a map layer can be qualitative (number of buildings, total floor area, total energy consumed) or quantitative (plot ratio, energy density etc).

Single-hue progressions fade from a dark shade of the chosen colour to a very light or white shade of relatively the same hue. This is a common method used to map magnitude such as energy

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[9] http://resources.arcgis.com/en/help/main/10.2/index.html#//009z0000000s000000

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demand. The darkest hue represents the greatest number in the data set and the lightest shade representing the least number. Choosing the right hue, e.g. red for heat demand or blue for cooling demand will also increase the user experience.

4.1 Post processing of layer

In the cases where the available data cannot be illustrated in a map with a sufficient detail i.e. where data is available only on the level of an administrative area (case 2 of the above section), a choropleth map cannot be considered as a realistic representation of the energy demand that can be used for the analysis required in the Comprehensive Assessment but just an aggregation for the specific region.

It is possible to refine the data and improve the accuracy of the end result by converting the map to the so called dasymetric map. This modern technique has been used to improve the spatial distribution of population in order to provide more accurate data. For this task the raw data are combined with other ancillary data such as land use in order to improve the disaggregation process by allowing the discrimination of distinct functional areas and respective densities [7-9].

Using this technique the energy data are redistributed from choropleth map zones (e.g. postal codes) to dasymetric map zones based on a combination of areal weighting and the estimated population density of each ancillary class (Figure 10). This procedure involves the use of the tools Zonal Statistics (Tabulate), Vector to raster transformation, and Map Algebra and can be found in the above mentioned sources.
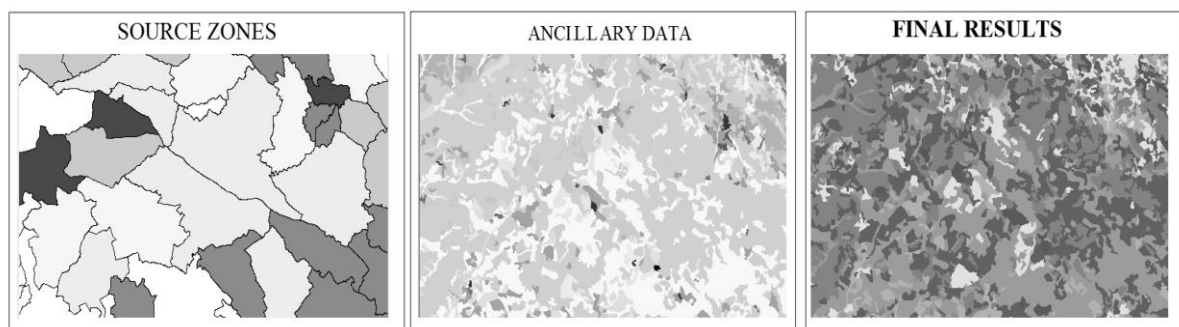

Figure 10 Construction of Dasymetric map

Raster resolution is a crucial parameter, which usually depends on the available resolution of the ancillary data. Some public datasets that can be used as ancillary maps are shown in Table 3. Other non-public datasets, such as information from urban planning zones, plot ratios or the national cadastre can also be used.

Table 3 Public datasets that can be used as ancillary data

Name	Author	Type	Information	Resolution
Corine Land Use Data	EC supported by EEA	Raster	Land use classes	100m, 250m
Global Human Settlement Map	EC JRC [10] (S.Ferri et. Al, 2014)	Raster	Built up	10m, 100m
Urban Atlas	EC DG REGIO, DG GROW supported by ESA and EEA	Vector	Soil sealing	-

These datasets can be used either individually or in combination with each other in order to produce a more accurate weighting layer. For example the "Corine Land Use" layer can be used to mask out areas classified as industrial from the "Global Human Settlement Map" in order to ensure that the residential energy demand is not allocated in areas that have industrial buildings.

Figure 11 shows a close-up of the input layers used for this procedure. The source layer is a choropleth map containing heat demand for residences per region. A close-up of two regions is shown in this example. Global Human Settlement map is used as ancillary data.

Figure 12 shows the result of this procedure. For this illustration, a topographic basemap was also included in order to show that this method allows avoiding allocation of the heat demand to territories with no residences. The raster contains 10 m cells, and each one of them contains a value about energy demand. Since all cells have exactly the same size there is no need to normalize them for the final result.
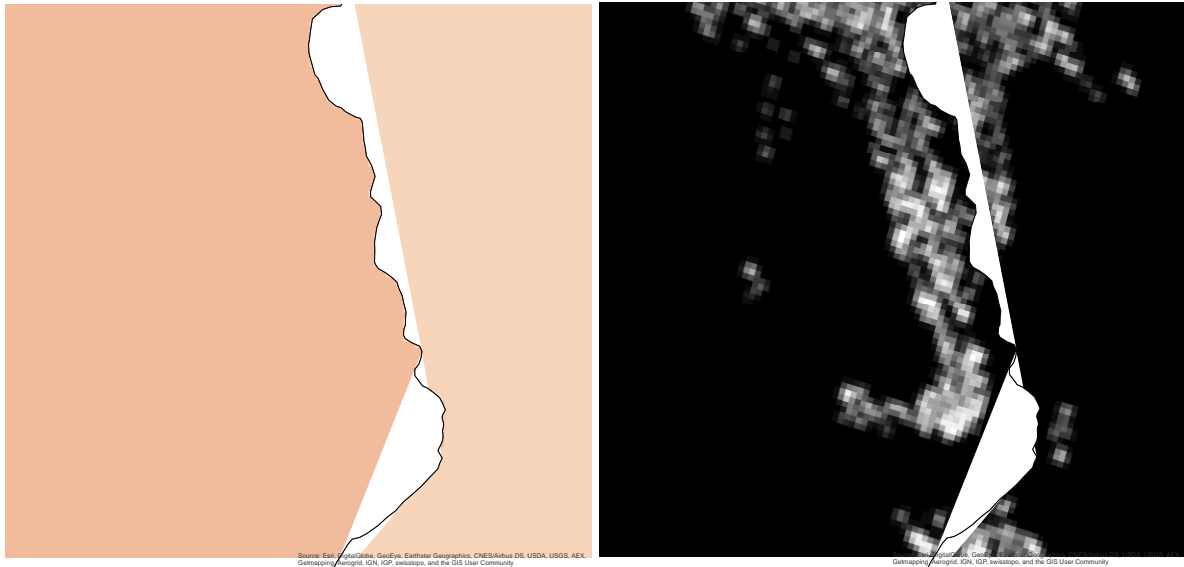
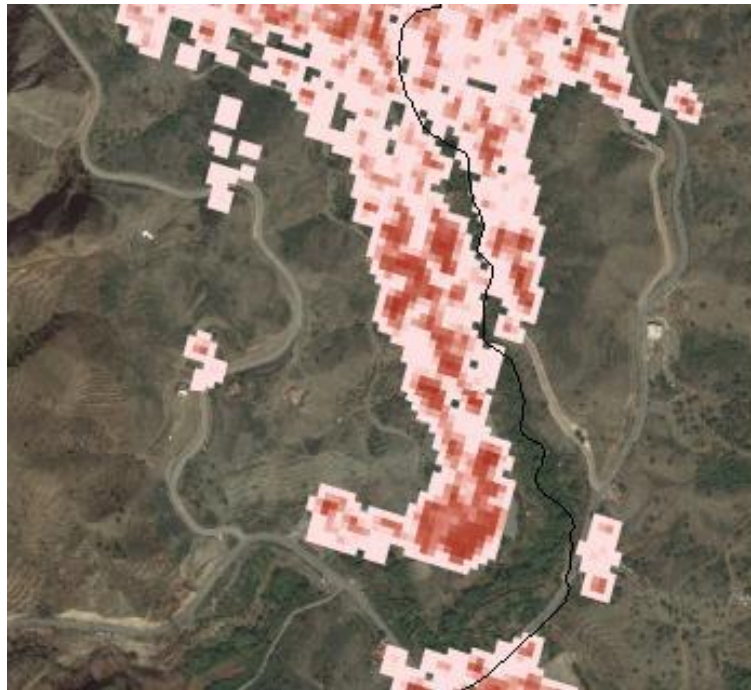Figure 11 Close-up of source and ancillary layers

Figure 12 Close-up of produced dasymetric layer

The produced layer has to be verified against the source data. This is done by adding all cells in the dasymetric layer and comparing it with the sum of all the source data features. The Zonal Statistics tool can be used for this task. This tool shows the sum of all cells that fall under a specific region defined by the borders of the choropleth source map. Minor divergence of ±5% is acceptable which is usually caused by rounding errors and cells that exist on the borderline of two features. The better the resolution, the lower the error will be.

5   Use of the map during preparation of CA

Since the heat map of a national territory will contain information about different aspects of heating and cooling consumption and supply, it should be integrated into the CA and should not be viewed as a stand-alone task. This means that the heat map should be used as a decision making tool in order to facilitate a better understanding of geographical relationships between different actors of heating and cooling consumption and supply processes.

The most important part of the CA where the heat map will be most useful is for linking heat sources and sinks. This task requires spatial information and assumptions on different thresholds.

GIS software contains many useful tools for geospatial analysis which can be employed for solving of wide variety of tasks. This chapter of the methodology intends to provide examples on selected options and it should not be considered as a complete guide on this extensive subject.

5.1   Most common GIS operations

The produced heat map will not only be used for the dissemination of the information to the public, but it is an important tool for the analysis done in different steps of the comprehensive assessment. The most important GIS operations that will be used to analyse the information contained in the heat map are the following:

Buffer

An often used geospatial analysis function is the creation of buffer zones. This function allows users to create new test objects using a distance, defined by the user, from existing objects. Buffer zones can be created around both points and areas. An example of buffer zone, created around municipality, is presented in Figure 13.
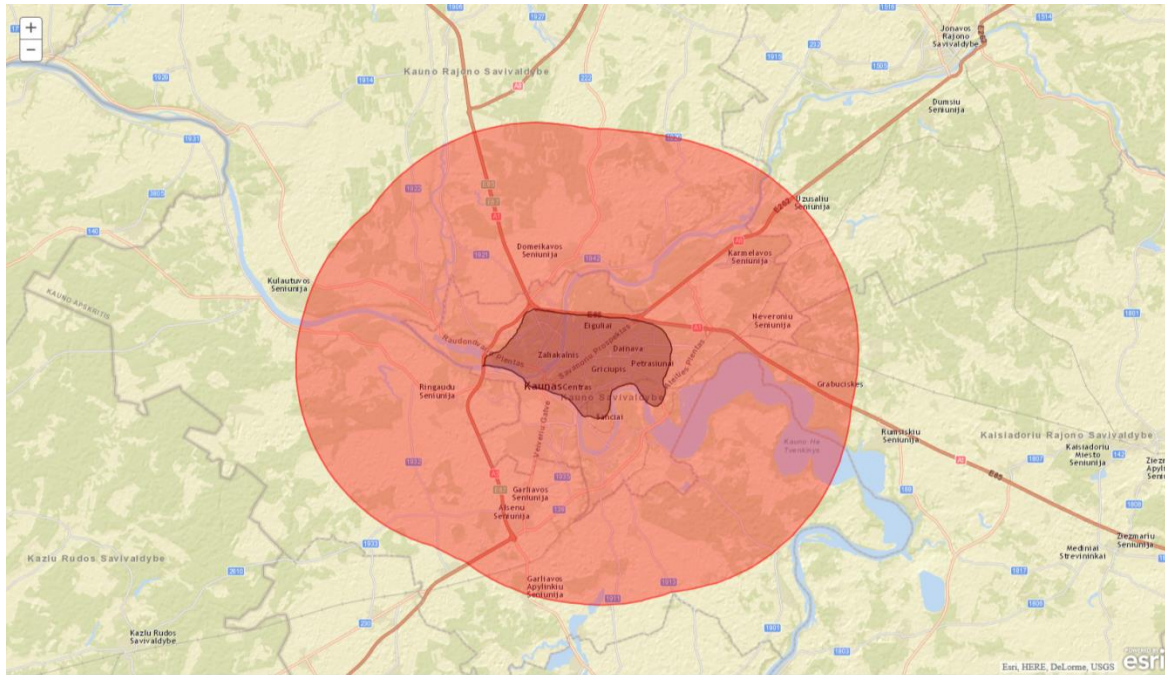
An identified heat demand area in Figure 13 is surrounded by buffer zone of 20 km.

A buffer zone tool can be employed during the preparation of the CA for identification of technically suitable heat links between heat demand areas/points and potential sources of waste heat as described in Section 2.2 of Deliverable 1.

A buffer zone can be created using a uniform distance (called threshold distance) from the heat demand area/object. The threshold distance can be the same for all the objects of the same type or it can be stored as one of the attributes of the object. For instance, the threshold distance can be made dependant on the size of heat demand or supply.

Overlay

Another widely used GIS analysis tool is the overlay toolset. Overlay refers only to vector layers and can be arithmetic or logical. During arithmetic overlay of two geographical data layers, values of one of them are added, subtracted, or split by the data of other layer. During logical overlay of two layers, one can find the intersect, union or difference of the features contained in two vector layers,. For instance by laying information about green spaces over information about build-up areas, one can isolate features, covered by buildings and therefore make more accurate calculations (see Example 5 in Sub-section 1.3.2 of Deliverable 1). However, many class-based layers (such as land-use) are available in raster format so it is common to convert vector layers to raster and use the more powerful Raster algebra tool that is described below.

Map Algebra – Raster Calculator

Any kind of mathematical operation between raster layers (of the same resolution) can be made via the map algebra tool such as simple addition, or subtraction of quantities on a cell-by-cell basis. This is useful, e.g. if someone needs to sum the demand of different layers into a single one, or if there is a need to apply weighting factors or derive any new information from existing data.

By combining other Boolean algebra tools (e.g. Conditional – SetNull tool) it is possible to use the Raster calculator for many other operations, such as using a layer to mask some areas from another source layer. This can be done, by setting cell values of the masked layer to 0 and multiplying with the source layer. The mathematical operations can contain more than one layers and numbers. This tool is actually a much more powerful version of the overlay tool described above which applies only for raster layers. It is used a lot during the construction of dasymetric maps.

Zonal Statistics tool[10]

With the Zonal Statistics tool, a statistic is calculated for each zone defined by a zone dataset, based on values from another dataset (a value raster). A single output value is computed for every zone in the input zone dataset. The results can be returned either in the form of a new raster image (single statistic) or a Table (all statistics)

A zone is all the cells in a raster that have the same value, whether or not they are contiguous. The input zone layer defines the shape, values, and locations of the zones. An integer field in the zone input is specified to define the zones. A string field can also be used. Both raster and feature datasets can be used as the zone dataset.

This tool can be very useful when someone wants to retrieve information from the layers. For example it is possible to estimate how much energy demand is found in industrial zones, or to estimate the mean/maximum/minimum energy demand in a specific administrative boundary.

In Figure 14, the Zone layer demonstrates an input raster that defines the zones. The Value layer contains the input for which a statistic is to be calculated per zone. In this example, the maximum of the value input is to be identified for each zone.

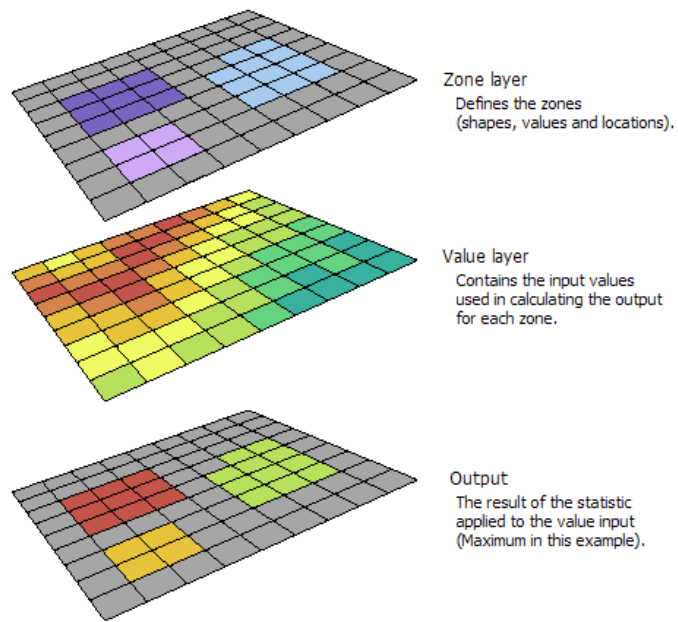[10] http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//009z000000wt000000.htm

Figure 14 Illustration of zonal statistics tool

6 Elements of the web-based public heat map

Public heat maps usually exist in the form of web applications. Several platforms exist and are ready to host GIS layers of different forms. Such platforms consist of two parts:

1. A backend which is a data server that hosts all layers and all relevant data models;
2. A frontend which is a web based user friendly interface with a user experience similar to other commonly used mapping platforms.

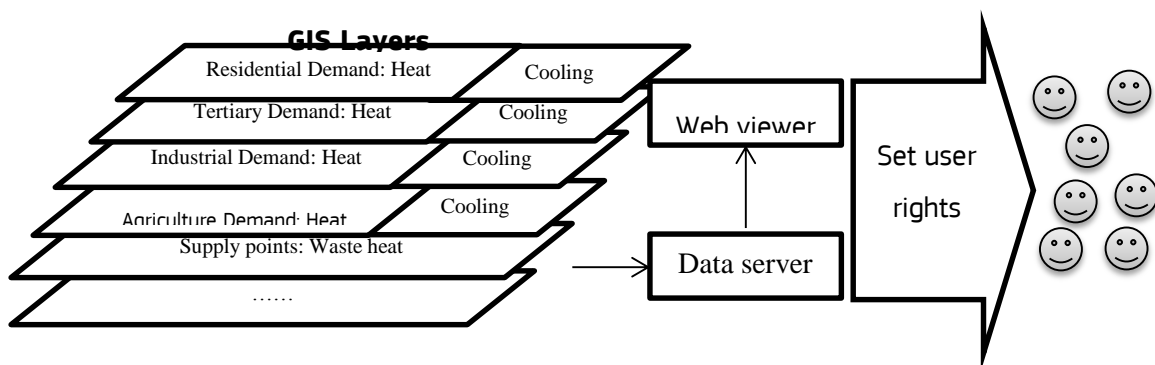Figure 15 shows the basic elements of a web-based heat map.

Figure 15 Information flow of a public heat map

The EED concedes to the need of preserving commercially sensitive data. Some data used in the heat mapping might be publically available without restrictions, but other data might be a property of some institutions and thus some restrictions to its public access might apply. To present data in raster format of sufficiently low resolution is a possible way to hide sensitive data.

6.1 Heat map backend

The backend of the heat map consists of a data server (hardware and software) that can host GIS files. Most popular GIS applications offer the possibility to serve GIS layers to the public. It is recommended that the heat map, prepared as part of CA, should be served by a dedicated server.

The heat map prepared for the comprehensive assessment will include layers for a specific base year. The possibility to add the time dimension should also be examined, in order to include forecasts or update the information when needed.

Along with the above, base maps should also be included into the heat map for easier recognition of locations of different heat demand and supply infrastructures. Base maps will form the background layer of information, upon which all other layers of the heat map will be displayed.

There are different sources of such maps, for instance Google Maps[11], Microsoft Bing Maps[12] or ESRI[13].

Ancillary layers will also have to be included such as a geographical/topological base map, regional boundaries, urban planning zones etc. Optionally, the same platform can host other relevant layers, such as renewable energy potential, electricity/natural gas grid etc. in order to give a better overview of the energy situation.

The layer format has to be decided carefully in order to serve the best and most responsive user experience. Usually raster files are better for most cases since they can be downloaded progressively depending on the zoom level.

While a vector shape file that has energy population information on a NUTS 2 level would certainly be smaller than a raster tile set rendered to cover the entire country at multiple zoom levels, the Block Group Shape file is too large (close to 1GB) for a web browser to download in demand. Even if the web browser could download the file quickly, most web browsers are quite slow when rendering huge numbers of shapes. So, for viewing large vector datasets, users are going to have a smoother and more responsive experience if all layers are converted into compressed raster images for transmission to the web browser.

6.2 Heat map frontend

The user interface of the heat map of a national territory should contain at least these structural elements: legend, scale, textual information, and the actual map. A map should be as self-explanatory as possible, so that it is easy to understand what the map presents without consulting the legend (e.g. for quantitative data). It is recommended to follow the visual rules according to the thematic information and the used visual variables [11][14].

The map legend should identify each of the theme variables used in the map as well as which visual variable corresponds to which theme variable [12].

This means that the variable which has been used for mapping should be explicitly stated. The units of measurement of different attributes (such as kWh/m²) should be identified in the legend.

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[11] http://google.com/maps

[12] http://bing.com/maps

[13] http://www.arcgis.com/home/webmap/viewer.html?useExisting=1

[14] http://ec.europa.eu/eurostat/documents/4311134/4366152/GISCO-desktop-mapping-guide.pdf/1caa840d-4fc1-4dbc-92f6-119879377e4b

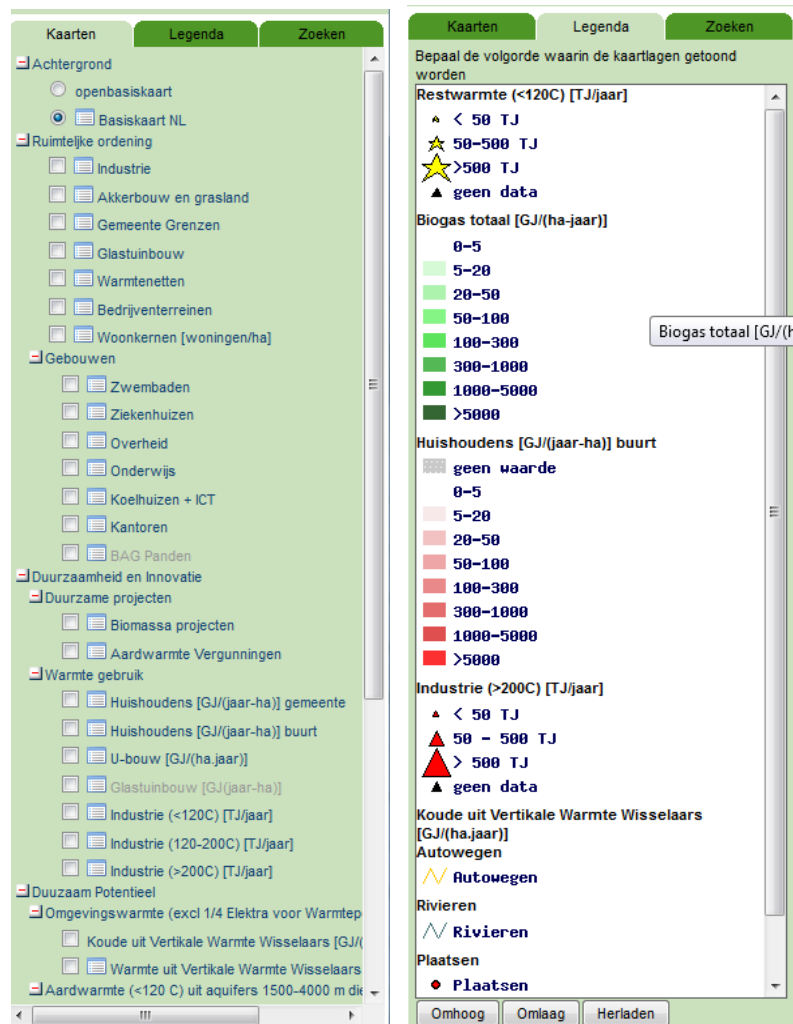An example of composite heat map legend from Heat Atlas of the Netherlands is presented in Figure 16.

Figure 16. Example of the heat map legend (source Heat Atlas of the Netherlands.[15])

The map scale is one of the most important elements of the map. The heat map should be able to represent the territory of the country in different scales. Different territorial division units of the country (such as NUTS and LAU regions, municipalities, postal districts and so on) might be represented using progressively larger scale maps which would represent map features in greater detail. Ability to select different scale maps can be integrated into the heat map through sliding scale selector or zoom-in and zoom-out buttons.

Textual and graphical information about different heating and cooling demand areas and points or waste heat sources might be made available to the user in different ways. Information about

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[15] http://agentschapnl.kaartenbalie.nl/gisviewer/viewer.do?code=0f2d31b5cee824a43bf2ad238f41d101

selected map features might be represented in the form of a table or in the form of pop-up information as can be seen in Figure 14. Some important information that can be shown on demand could be the following:

- Area (m^2)
- Municipality name
- Municipal household use of heat [GJ / year]
- House density [houses / m^2]
- Heat household use [GJ / (m^2–year)]
- CO_2 emission by using heat [kg CO_2 / resident]
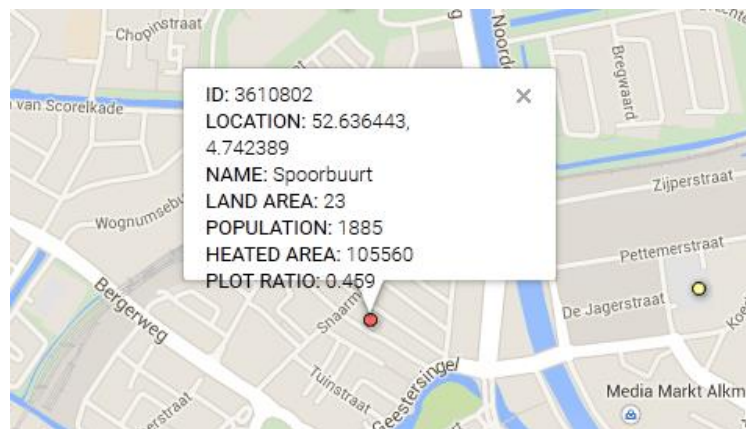- Land use category etc.

Figure 17. Example of pop-up presentation of information (source of background map Google Maps).

Various tools have also to be available in order to allow the user to browse the map. The user should be able to pan the map, activate/deactivate different layers and perform basic operations on it such as: zooming in/out, selection of region by polygon tool etc. Other reporting tools can be integrated such as summation of information from different layers.

Other guidelines about visualization of the information contained in the map can be found in [12].

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