REDUCING ENERGY CONSUMPTION AND CO_2 EMISSIONS IN CITIES ACROSS CENTRAL EUROPE

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EnergyCity SDSS: A Perfect Tool for Sustainable Urban Development

For a city administration dedicated to reduce CO_2 emissions, a broad bouquet of possible measures is available. For municipal buildings itself, the most crucial data is present in the city's files and accounting system – albeit sometimes hard to mine – so energy saving and emission reducing measures can be relatively easy to calculate and evaluate. In the present situation of continuously rising fuel prices and severely stressed city budgets, many energy saving improvements yield in a fast payback of the invested money and a relief for the treasury department. Needless to say that every city administration now gives great precedence to low-emission or even zero-emission standards when it comes to the construction of new buildings. But: public buildings account for only a small fraction of a city's building stock, and therefore the result of all those improvements is not enough to reach the 20-20-20 goals. The majority of buildings in the city of Munich belong to private house owners or companies of all sizes.

For decades the city administration has offered advice to house owners, for the future as well as the present. Since priority has been given to energy saving and emission reduction, a lot of this advice focuses on insulation and the improvement or exchange of the heating system and/or the energy source. The city has even set up a multi-million subsidiary program to provide incentive for house owners to energetically renovate their buildings. But the motivation for such measures had and has to be calculated in dry numbers of present and future costs, hard to understand and not convincing at first sight. And here the EnergyCity Heat Loss Maps come into play: while sheets of calculations, based on estimations and extrapolations are less than appealing, a look at a Heat Loss Map is just the contrary for the house owner: if the house is in a worse heat loss class than that of many neighbours, the immediate feeling created is that of avoidable expenditures, of money thrown out of the chimney for heating energy that doesn't warm the house but dissipates into the atmosphere, with additional dire consequences for the climate.

And so the results of the EnergyCity project do really shine: Different to the thermal imagery of a singular facade they offer the possibility to compare, and they show that less waste of expensive heating energy is possible.

Given that it would be possible to cut down the costs per analyzed square kilometer, the EnergyCity Heat Loss Map could provide an excellent tool to educate house owners (and many tenants) on the possibility of energy saving and CO_2 reduction.

1. The Central Europe Programme

CENTRAL EUROPE is a European Union programme that encourages cooperation among regions of nine central European countries: Austria, Czech Republic, Germany, Hungary, Italy, Poland, Slovakia, Slovenia and Ukraine. It aims to improve innovation, accessibility and the environment and to enhance the competitiveness and attractiveness of their cities and regions.

CENTRAL EUROPE invests €231 million to provide funding to transnational cooperation projects involving public and private organizations from the countries of the programme area.

The programme is financed by the European Regional Development Fund and runs from 2007 to 2013. However, the CENTRAL EUROPE Programme will continue to support regional cooperation among central European countries in the upcoming programming period (2014-2020). Key variables of the new programme are currently under discussion.

CENTRAL EUROPE provides funding for cooperation projects covering four priorities:
Priority 1: Facilitating innovation across Central Europe
Priority 2: Improving accessibility to, and within, Central Europe
Priority 3: Using our environment responsibly
Priority 4: Enhancing competitiveness and attractiveness of cities and regions

The EnergyCity project is implemented through the CENTRAL EUROPE Programme (Priority 3) co-financed by the ERDF. The project runs between March 2010 and August 2013.

1 | CENTRAL EUROPE programme area |

2. Scope and objectives of the EnergyCity project

With the era of affordable and abundant energy long since past, saving energy and reducing waste has become one of the top priorities of the European Union.

There are several possible areas of intervention, with building energy management having one of the greatest potential in terms of cost-effectiveness an overall emission reduction potential. A key part of the solution for better urban energy management is a better understanding of our current practices and the status quo, and that includes getting an accurate picture of where heat escapes from buildings.

To contribute to these goals, the EnergyCity project is gathering aerial thermography data on 7 cities in Central Europe (Budapest, Prague, Munich, Bologna, Treviso, Ludwigsburg and Velenje), which are then processed and refined into an online Spatial Decision Support System (SDSS) to visualize and compare the cost-effectiveness and potential of different energy efficiency solutions in the project cities. A series of pilot actions on municipal level demonstrates the application possibilities of the tool.

3. The Spatial Decision Support System (SDSS): An aerial thermographic support tool for decision makers

The most important product of the project is the Spatial Decision Support System. It is an online web-based software, developed for city administrators and decision makers.

The geographic information system tool is available on the project website:

http://www.energycity2013.eu/webgis.php

To log in a password is needed that can be requested by simply writing an e-mail to:

siro.martello@corvallis.it.

In the following chapters, the SDSS tool will be presented focusing on the main features and application possibilities. The methodology behind the tool is described in the chapter "Technical Background".

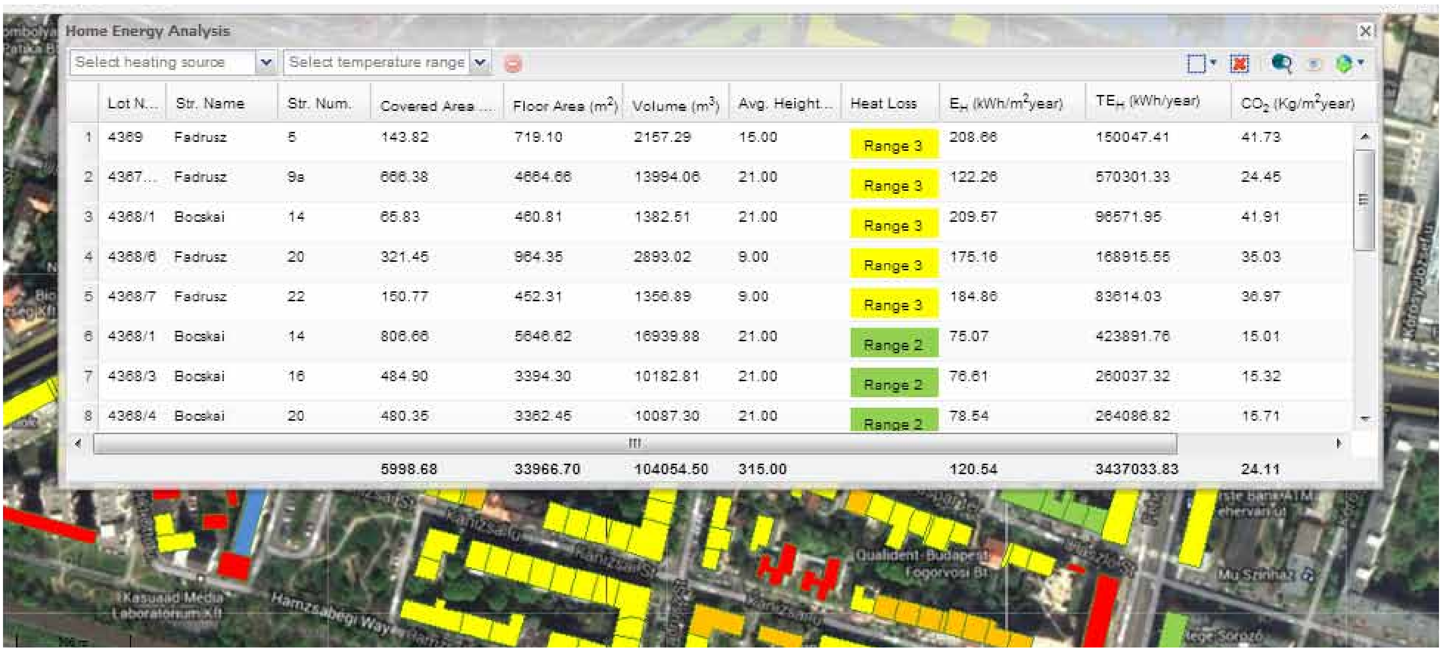
3.1. SDSS: How to use?

The software developed combines mapping functionality in the form of a web-based spatial decision support system with energy efficiency measures to delineate and quantify measures and strategies to reduce CO_2 emissions and energy usage in the project cities. The software uses a mapping tool to display heat loss maps representing the baseline CO_2 emissions in the cities as well as all other mapping outputs produced by the project. The image shows the graphical user interface with the map window on the right (where maps are displayed) and the list of available maps on the left.

2 | The SDSS graphical user interface |

Local planners and decision makers from the project cities can use the software to plan emission reduction strategies, make informed decisions and verify alternatives in terms of the most cost-effective energy efficiency solutions to be implemented. This is exemplified in the image below, where the Home Energy Analysis window is displayed on top of the heat loss maps with building data for the dwellings selected from the heat loss map and important data containing an assessment of the energy performance of those houses.

The Home Energy Analysis window contains information on specific primary heating energy consumption (consumption of electrical appliances is not considered), total primary heating energy consumption, specific CO_2 emissions and total CO_2 emissions levels.



	Lot N...	Str. Name	Str. Num.	Covered Area ...	Floor Area (m²)	Volume (m³)	Avg. Height...	Heat Loss	E_H (kWh/m²year)	TE_H (kWh/year)	CO_2 (Kg/m²year)
1	4369	Fadrusz	5	143.82	719.10	2157.29	15.00	Range 3	208.66	150047.41	41.73
2	4367...	Fadrusz	9a	666.38	4664.66	13994.06	21.00	Range 3	122.26	570301.33	24.45
3	4368/1	Bocskai	14	65.83	460.81	1382.51	21.00	Range 3	209.57	96571.95	41.91
4	4368/6	Fadrusz	20	321.45	964.35	2893.02	9.00	Range 3	175.16	168915.55	35.03
5	4368/7	Fadrusz	22	150.77	452.31	1356.89	9.00	Range 3	184.86	83614.03	36.97
6	4368/1	Bocskai	14	806.66	5646.62	16939.88	21.00	Range 2	75.07	423891.76	15.01
7	4368/3	Bocskai	16	484.90	3394.30	10182.81	21.00	Range 2	76.61	260037.32	15.32
8	4368/4	Bocskai	20	480.35	3362.45	10087.30	21.00	Range 2	78.54	264086.82	15.71
				5998.68	33966.70	104054.50	315.00		120.54	3437033.83	24.11

3 | The Home Energy Analysis window |

The image above shows an overview of the results of the analysis that is available within the Home Energy Analysis window.

After selecting a number of items of interest on the map using a point, line or polygon selection, the selected items will appear in the Home Energy Analysis dialog with the following information for each selected building:

EH: specific primary heating energy consumption (consumption of electrical appliances is not considered)

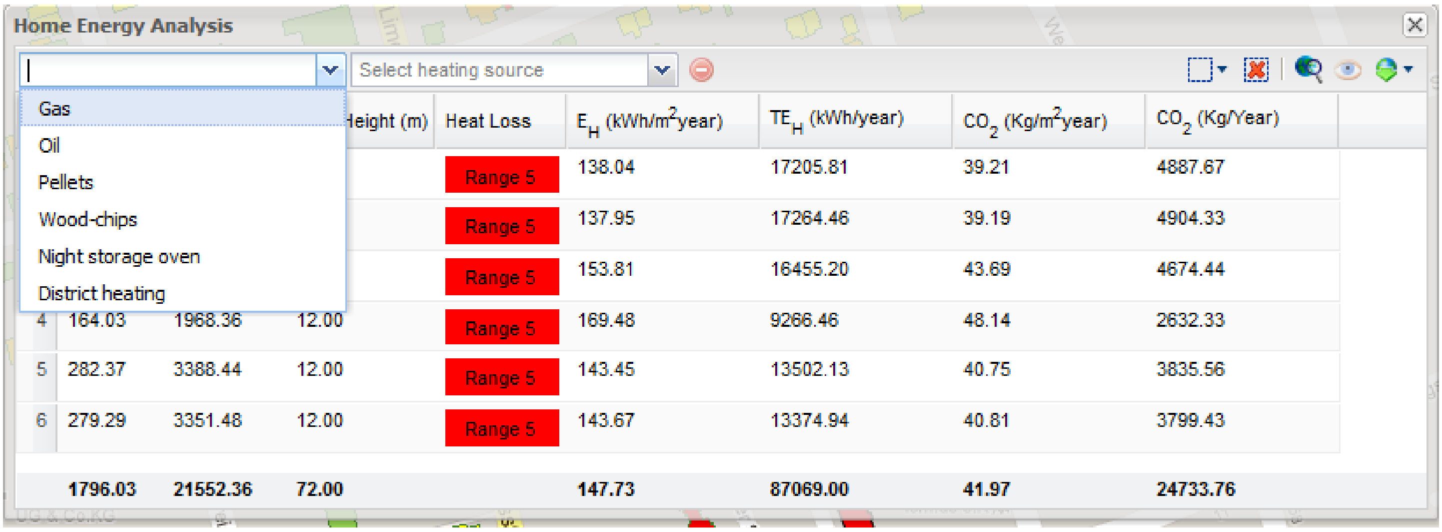
TEH: total primary heating energy consumption

CO_2: specific CO_2 emissions (per floor area unit)

CO_2: total CO_2 emissions

The bottom row of the dialog displays the sum or the average of the values of all the buildings. Clicking on a row will highlight the corresponding item on the map and make the map window map to the item.

An additional feature of the software is the ability to visualize, inside the mapping tool, scenarios of emission reductions through the introduction of renewable energy measures. One of the measures available to construct such scenarios is the use for a number of selected buildings of a different fuel source in order to calculate different levels of CO_2 emissions. After choosing a new heating source from the drop-down box on the top left hand-side corner, a new series of important energy parameters is displayed in the table underneath. The image below shows how the user can choose a different heating source to obtain new scenarios of energy consumption and CO_2 emissions.



			Height (m)	Heat Loss	E_H (kWh/m²year)	TE_H (kWh/year)	CO_2 (Kg/m²year)	CO_2 (Kg/Year)
				Range 5	138.04	17205.81	39.21	4887.67
				Range 5	137.95	17264.46	39.19	4904.33
				Range 5	153.81	16455.20	43.69	4674.44
4	164.03	1968.36	12.00	Range 5	169.48	9266.46	48.14	2632.33
5	282.37	3388.44	12.00	Range 5	143.45	13502.13	40.75	3835.56
6	279.29	3351.48	12.00	Range 5	143.67	13374.94	40.81	3799.43
	1796.03	21552.36	72.00		147.73	87069.00	41.97	24733.76

4 | Selection of the energy source |

3.2. SDSS: What is it for?

Data analysis

Measured roof heat maps

Using a series of different querying functions, the SDSS lets users find out the measured and corrected roof temperature of individual buildings. It is possible to perform a selection using a point, line or polygon. Buildings being intersected by these geometrical elements will be selected and displayed inside a table. Clicking on each row in this table changes the selection inside the map in the graphical interface.

Derived total building heating energy information

Using the measured roof heat temperature and additional architectural data about the buildings, the SDSS calculates the final heating energy consumption for each building. Using the querying functions of the system, it is possible to select each building and see – again in a tabular format - the value of this parameter. The system also calculates the primary heating energy consumption for each building and displays it in a similar fashion.

Derived CO_2 emissions information

The SDSS also calculates the specific CO_2 emission (without the emission of supplementary electric appliances) for buildings using the model explained elsewhere in this document. The value of CO_2 emissions for each building can be queried and displayed similarly to what is possible with roof heat and heating energy values.

Multi-scale spatial analysis

Selection of buildings at different scales (single, multiple, user-defined area)

The standard toolbar in the SDSS contains a series tools to perform selections of objects in the map window. The simplest selection tool is an identification pointer that, when hovered over a building, brings up a window displaying attributes for the underlying building, such as the roof temperature or other architectural characteristics. On a more advanced level, using the buildings querying functions mentioned above (point, line and polygon) users can perform selections at different scales. This means that a single building can be selected or the user can zoom out and select a number of buildings with multiple clicks. With the polygon tool, users can draw an area of any shape with the result that of all buildings in that area will be selected. Their attribute data will then be displayed in a table.

Aggregated display of CO_2 and heat data according to user's selection

Once a selection has been applied using the possibilities listed in the previous point, a home energy analysis can be performed. This is a collection of important CO_2 and heating energy valued displayed in tabular format. The parameters listed are: classes of relative roof temperature, final heating energy consumption, primary heating energy consumption and CO_2 emissions. These values represent the baseline energy and emissions figures.

Modification of fuel parameters for buildings and heat retention properties to generate scenarios of improvement

Once the baseline values have been calculated, it is possible to apply various strategies of reduction of both the heating energy values and the CO_2 emissions. These strategies are based on the modification of some of the values underlying the model used to perform the calculations and can take in to consideration the type of fuel used to heat the building and the overall insulation performance of the building. As the user selects a greener type of fuel (for instance pellets or wood instead of gas or oil), new parameters of heating energy consumption and CO_2 emissions are calculated and displayed in the table. Similarly, the baseline relative roof temperature can be changed to a better value, which, in a simplistic way, represents a scenario of insulation improvement for that building. New values of heating energy consumption and CO_2 emissions will be derived and displayed.

Scenarios of remedial measures and actions for decision makers

Publishing of on-the-fly scenarios maps

Once a reduction strategy has been applied as explained above, the new values of relative roof temperatures are displayed on the fly in the map window for the selected buildings allowing for an immediate visual inspection and comparison of the effects of the chosen improvement scenario.

Exporting of on-the-fly scenarios maps on local PC (shp, KMZ and dxf formats)

The new maps of relative roof temperatures, resulting from the implementation of improvement scenarios, can be exported to en external file in a variety of formats (ESRI .shp, Google KMZ and AutoCAD dxf) and saved for future reference and meaningful comparisons.

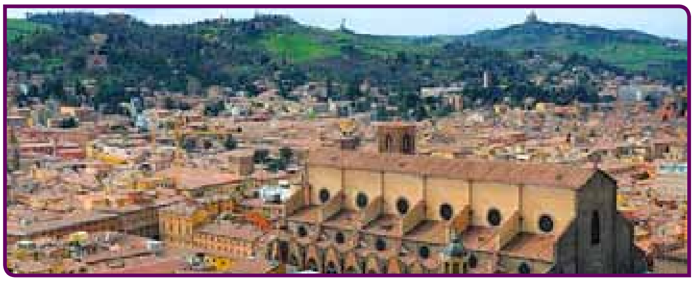
Distribution of on-the-fly scenario maps via WMS protocols to city server applications

The on the fly improvement maps can also be distributed to additional web mapping services and applications supporting WMS and WFS protocols. This means that users of external online web applications will be able to log on to the SDSS to perform advanced heating energy analysis of their urban areas and save the improvement scenarios in to their data repository in a seamless and efficient way.

4. Participating cities

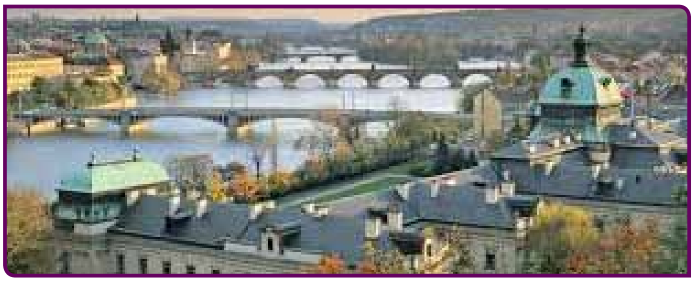
The thermal surveys have been carried out above the test areas in 7 cities. The surveyed covered roughly 20-40 square kilometres.

BOLOGNA



BUDAPEST

PRAGUE



VELENJE

MUNICH

LUDWIGSBURG

TREVISO

5. EnergyCity and the City - Case Studies

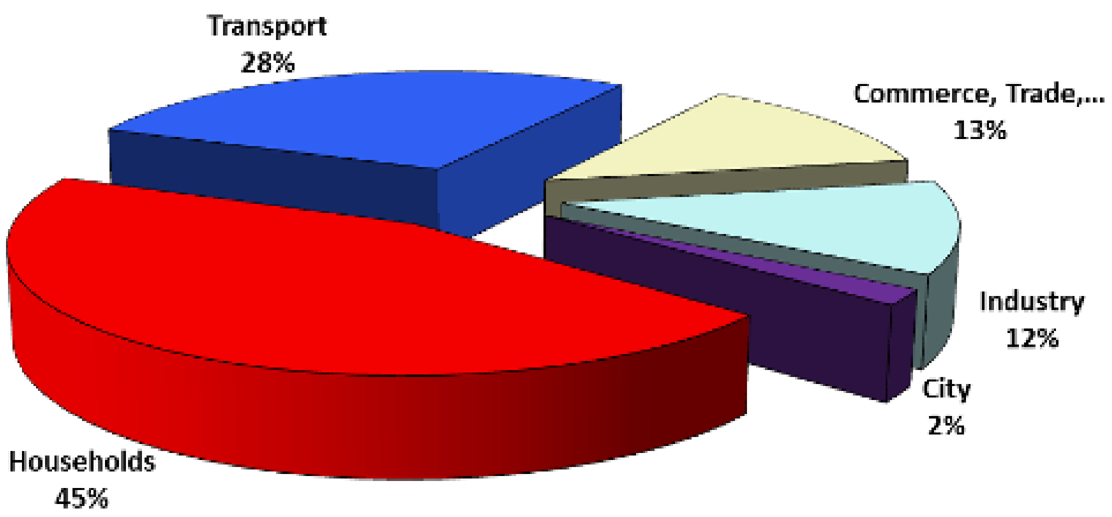
5.1. The Case of Ludwigsburg

Citywide perspective

The energy-related CO_2 emissions attributable to Ludwigsburg were calculated from examining the development of the energy demand and using energy carrier specific emission factors. A total of 539,000 t CO_2/a were emitted in Ludwigsburg in 2007. This averages 6.2 t CO_2/capita/a. In comparison to the average for the state of Baden-Württemberg (6.6 t CO_2 per capita and year), Ludwigsburg already performs slightly better, but in comparison to the national German average (9,2 t CO_2 per capita and year), Ludwigsburg emits much less on average. If the weather conditions are taken into consideration, then the emissions values for Ludwigsburg are such that a total of 576,000 t CO_2/a were recorded for 2007. The dominant sectors remain with households responsible for 45% of the actual emissions and transport responsible for 28%.

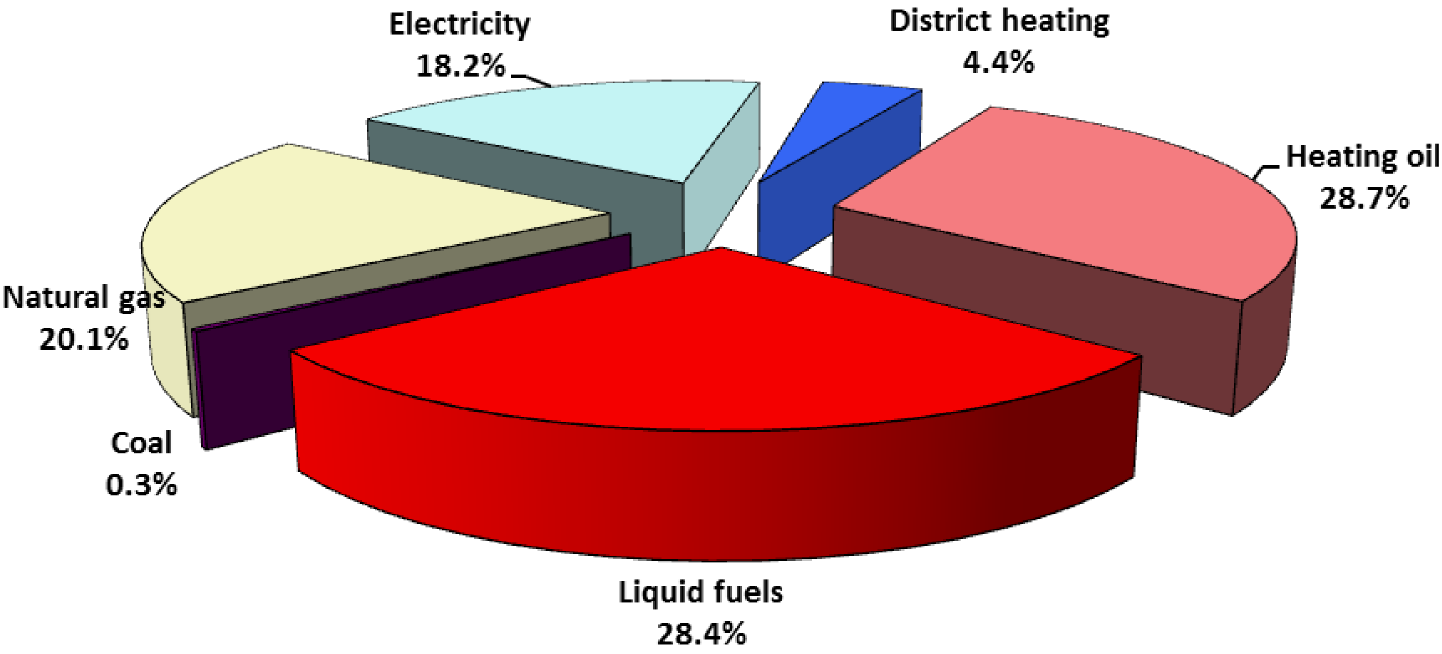
The actual CO_2 emissions in Ludwigsburg in 2006 totalled 592,000 t CO_2/a.

The energy related CO_2 emissions according to energy carriers shows that liquid fuels are accountable for a share of 28% and fuel oil for a share of 29%. Natural gas follows with a share of 20% and electricity with a share of 18%. Attributing the CO_2 emissions resulting from generating the district heating to the consumption



5 | *Energy related CO_2 emissions by sector in Ludwigsburg 2007* |

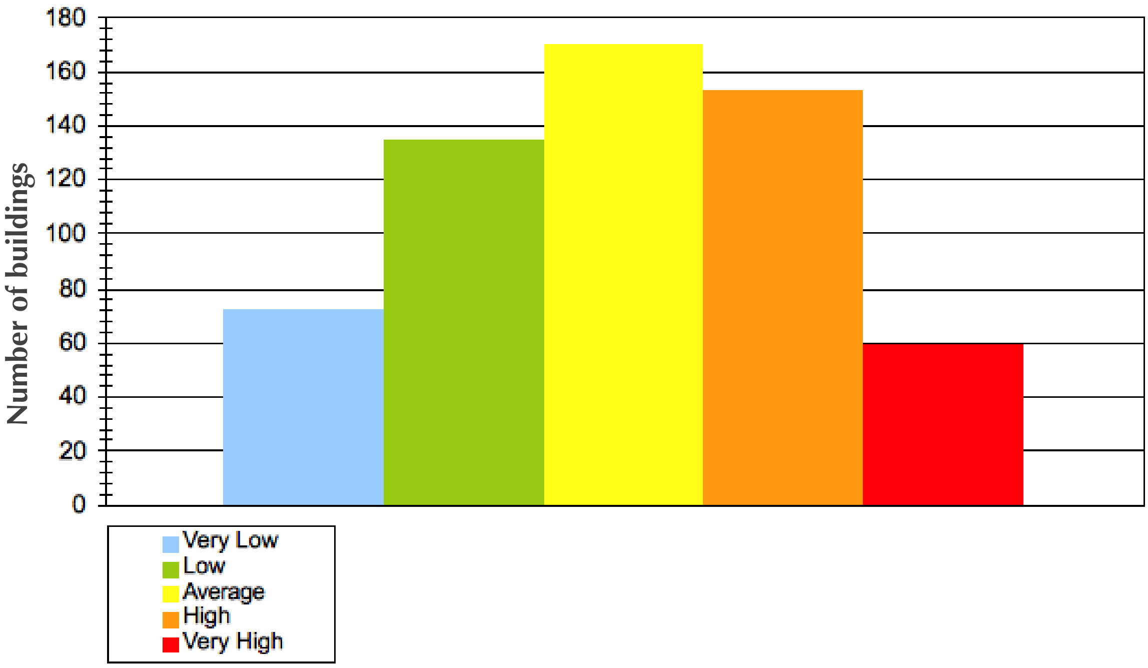
The CO_2 emissions in Ludwigsburg were reduced even further with the commencement of the wood burning power plant. This measure alone reduced the emissions by 18,000 t such that the emissions level achieved 521,000 t CO_2/a and around 6.0 t CO_2 per capita and year.



6 | Energy related CO_2 emissions by energy carrier in Ludwigsburg 2007 |

Test Area

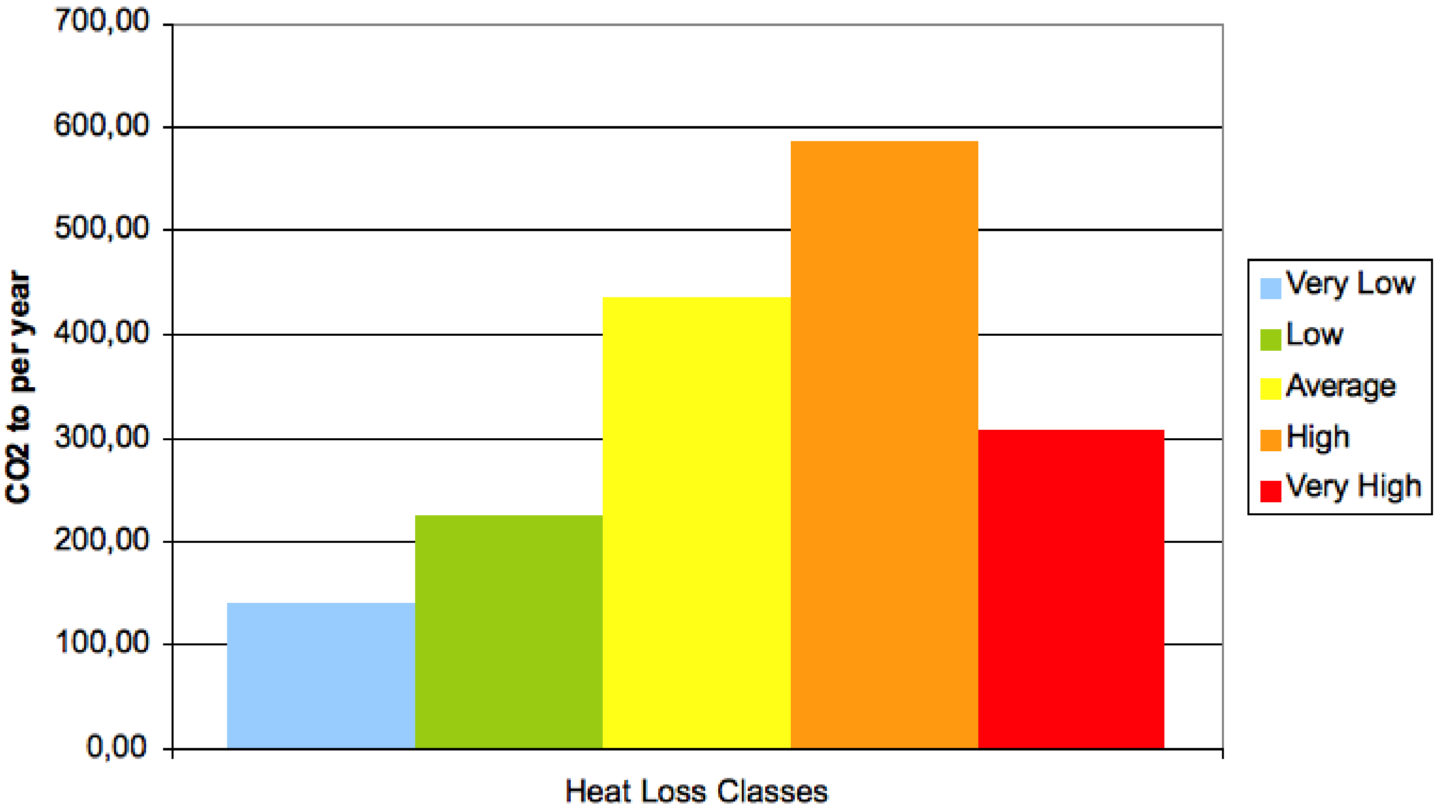
A total of 760 buildings are within the Test Area. The distribution within the five heat loss classes are shown in the next graph:



7 | Energy Distribution of the heat loss classes within the Test Area |

Nearly 30% of the buildings have an average value of heat loss. A total of 36% have a less than average heat loss class, but only 10% (60 buildings) have a very high Heat Loss Class. This means that 35% of the buildings have a lower heat loss than the average of the buildings within the district.

In a next step the heat loss classes have been compared to the carbon emission values of the district. The basic analysis was done with reference to the Carbon emission per building and year.



8 | Carbon emission in tons pear year |

The current emission in the Test Area totalled to 1.700 t CO_2/year. Using the EnergyCity methodology, the actual final energy demand in the northern part of the Test Area is around 7 GWh/a. In the southern part of the Test Area the energy demand is around 7,5 GWh/a. Furthermore the experts of the Energetikom calculated different refurbishment scenarios on the basis on engineering experiences.

Renovation measure	Renovation cost (entire quarter)	Effect cca.
façade	3.444.000 euros	40%
window	2.066.400 euros	2%
roof	5.904.000 euros	17%
façade / window	5.510.400 euros	42%
façade / window / roof	11.414.400 euros	50%

9 | Rehabilitation Scenarios |

The savings potential by changing all the windows results in a reduction of only 2%, because of the small number o windows and good standards to which they were made. The biggest saving potential is a scenario renewing facades, roofs and windows. This scenario equals a savings potential of nearly 50%.

Within the activities of the Pilot Area advises of the Ludwigsburg Agency were achieved. On basis of Onsite appointments specific refurbishment scenarios were deepened and discussed with the owners.

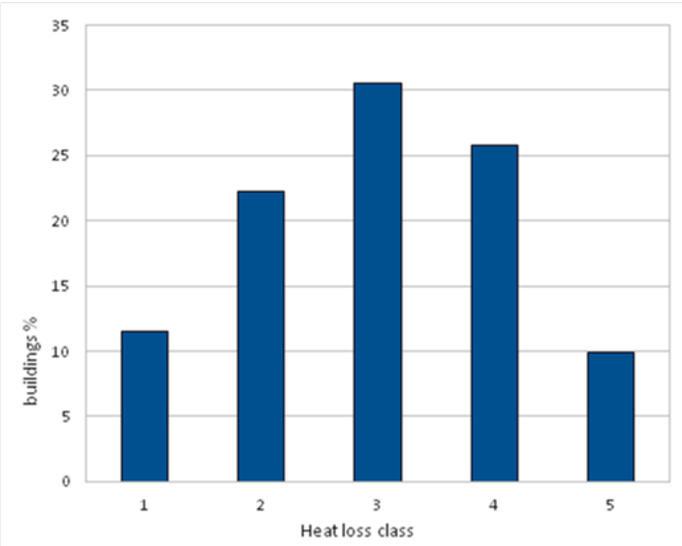
5.2. The Case of Munich

Being part of a bigger planning concept with a strong focus on energy saving measures, the city district of Neuaubing was chosen as the test area for aerial thermography and implementation of the carbon emissions database in Munich.

The calibration area for the carbon emission database has a diversified structure with building types ranging from single-family houses to multi-level apartment housing blocks. Data for 746 buildings was collected in a data sheet including heating type, building structure, and other energy-related information such as primary energy consumption.

The data was georeferenced with a GIS system for further analysis. A sample of 125 buildings comprising 5 visually detected roof types was taken from the dataset and forwarded to the project partners for further processing, input to the energy model and incorporation into the Carbon Emission Database on the EnergyCity website (see the figure).

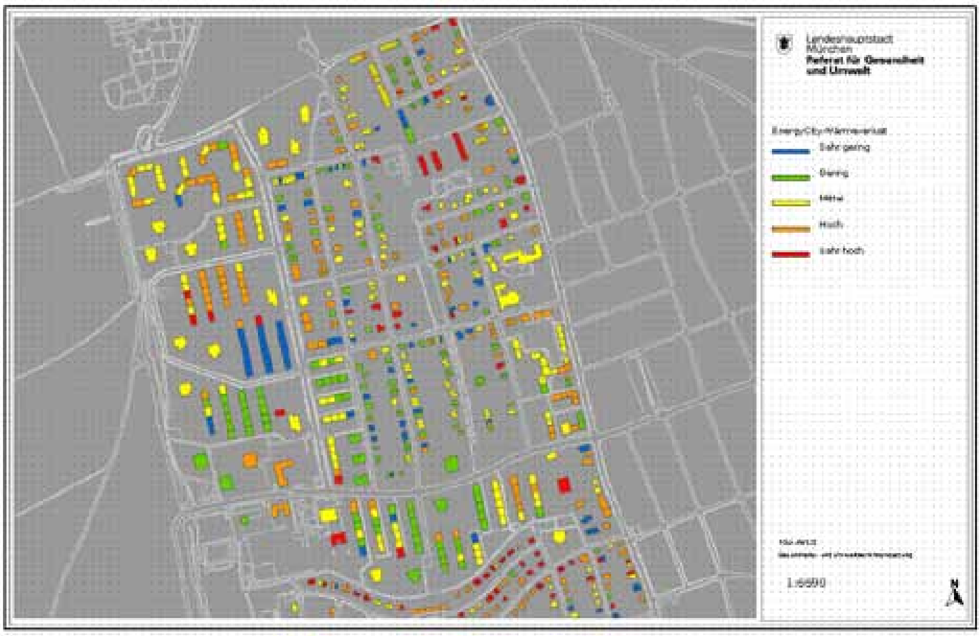
The results show a distribution close to standard with a peak in the average heat loss class 3 (31% of all buildings). 12% of the buildings analysed reach the best (lowest) heat loss class, whereas 10% of the buildings belong to the highest heat loss class. 34% of the buildings were assigned to the better-than-average heat loss classes 1 or 2, as opposed to 36% of buildings in heat loss classes worse than average.



11 | Percentages of different heat loss classes of buildings in the calibration area |

10 | Identification of roof types for sample buildings in the test site |

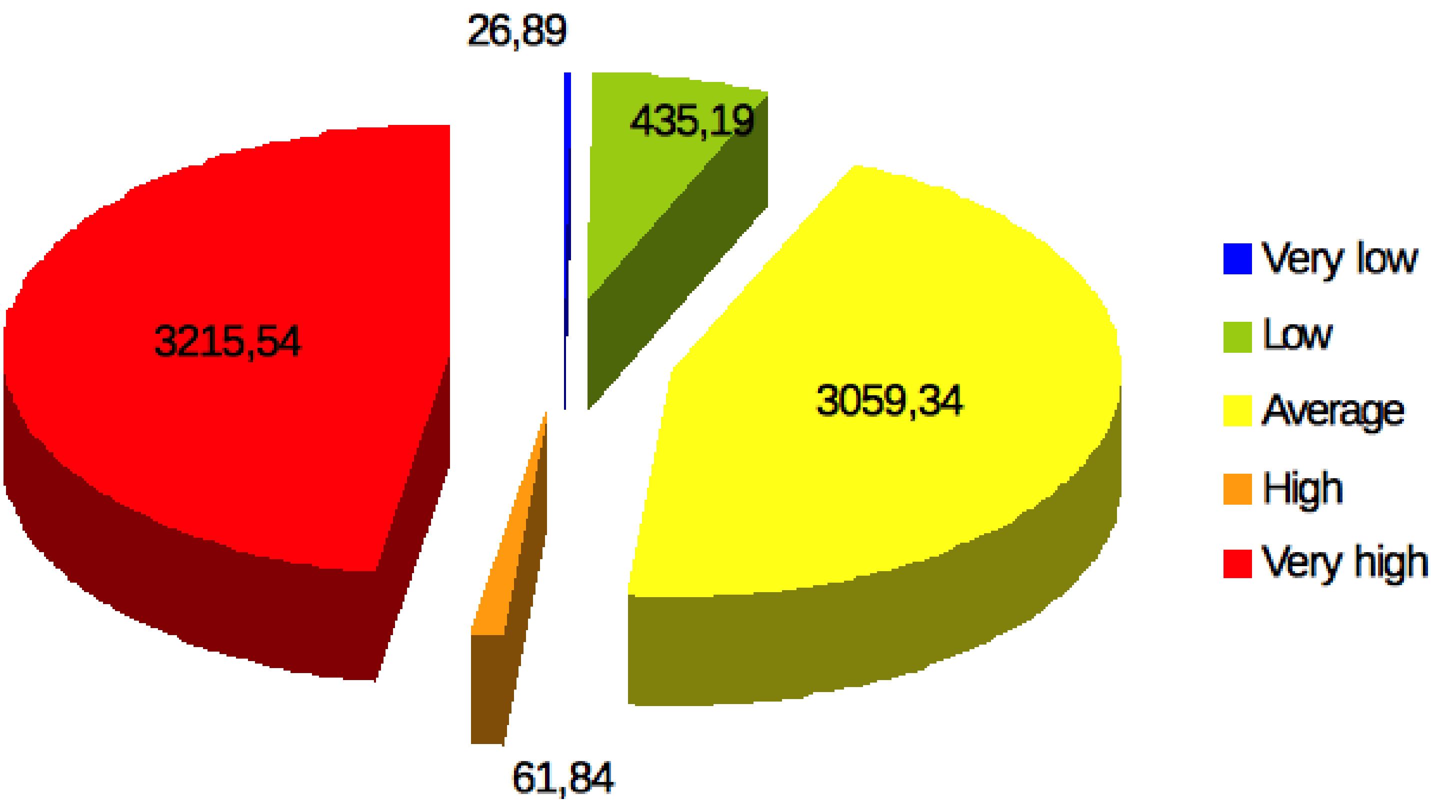
The results obtained from the heat loss thermal mapping were incorporated in a series of heat loss maps created with a GIS to be used in trainings and other dissemination activities in Munich, and they were used for creating the Carbon Mapping Database for Munich accessible via the EnergyCity WebGIS.



12 | Example map of heat loss classes derived from the results of the EnergyCity analysis |

5.3. The Case of Velenje

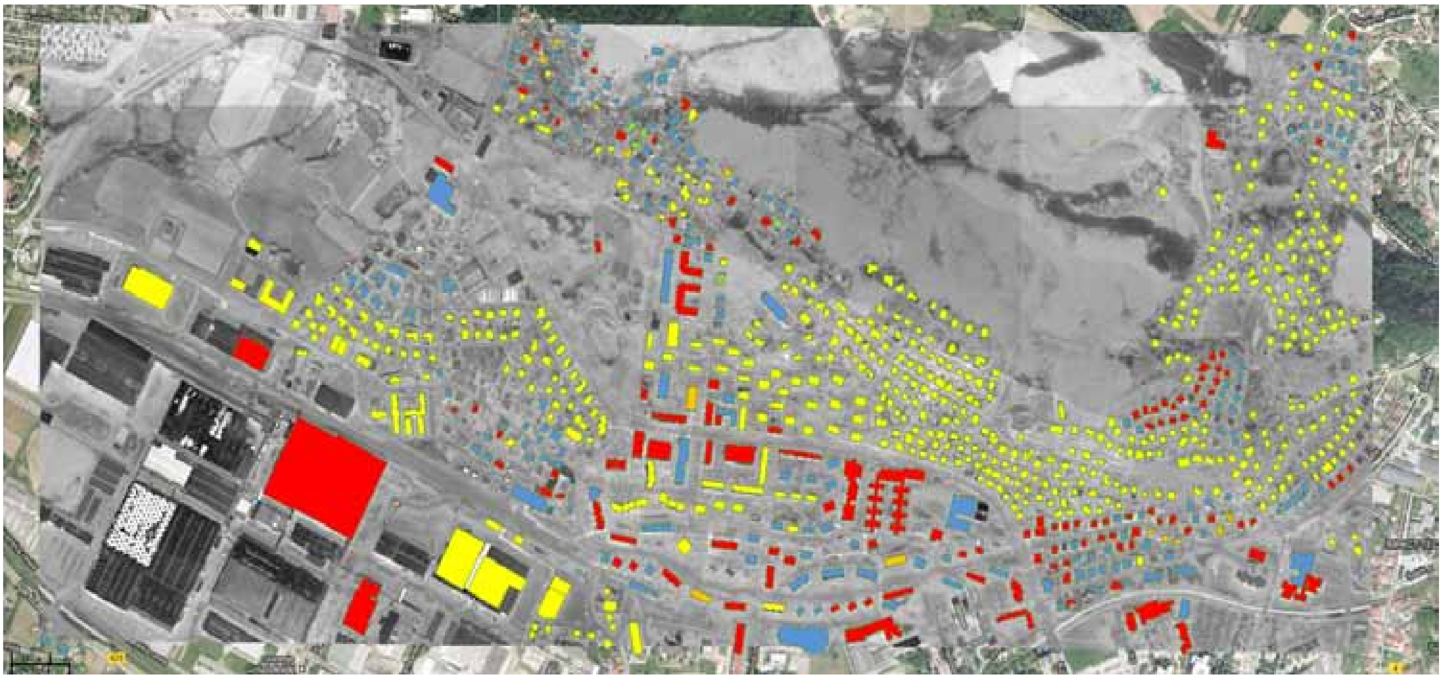
Reducing CO_2 emissions is one of the biggest tasks of the cities across the Europe, especially for cities that have additional commitments to reducing emissions with the Covenant of Mayors. Velenje is such a city. To achieve these objectives, is essential for Velenje to participate in projects that create a tool for the visualization of emission data sets. It is useful to compare carbon emission values of buildings according to their heat loss class. To this purpose the graph below has been produced.



13 | Share of CO2 emissions of the buildings in the Venenje test area |

This graph shows the total carbon emissions in tonnes of CO_2 per year. Over 48% of emissions are produced by buildings in the very high and high heat loss classes that represent 20 % of all buildings. Another 45% of emissions are produced by buildings in the average class (58% of all buildings). And finally 7 % of buildings are in a low or very low heat loss class. Buildings with very low heat loss are having almost no heating energy consumption and consequently do not have a substantial value for carbon emissions (less than 5%).
From the carbon emission analysis it is easy to see that the two building classes with the highest heat loss in the Velenje area, which includes 20% of the buildings, are responsible for almost half of the total carbon emissions of the area. Upon a closer look at the map, we can see that energy inefficient buildings are mostly

large production halls together with some public buildings and multi-residential buildings. With identifying the type of energy inefficient buildings, necessary interventions prepared for these buildings aimed at improving their energy efficiency would yield very positive results in the fight against carbon emissions. The other half of emissions are caused mostly one or two family houses, which local communities can influence by raising awareness about energy efficiency and some additional subsidies for implementing measures of energy efficiency according to Local Energetic Concept.



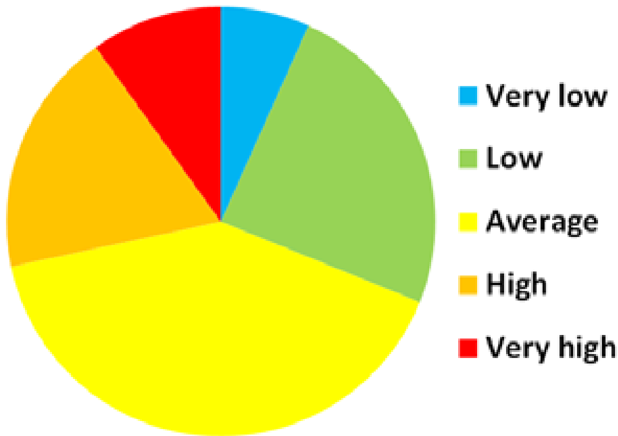
14 | Classified buildings in the heat loss map of Velenje |

5.4. The Case of Budapest

As with the other cities in the project, Budapest has been selected to carry out an investigation for the database of energy consumption. Thermal images and hyperspectral data has been acquired over the city of Budapest in an area of approximately 40 km2.

Case studies have been carried out for a smaller area of approximately 2.56 km2 with a total number of 656 buildings covered. Carbon emissions have been analyzed first, considering the heat loss classification. This classification rates the buildings according to their roof temperature and assigns each building to one of these five classes: blue or very low, green or low, yellow or average, orange or high and red or very high.

The temperatures between the ranges are set to be equal. The red class includes the 10% hottest roofs in the area (equal to 65 buildings), which consequently have the highest heat loss. The distribution of the buildings in the five classes is represented in the figure below.



15 | Heat Loss Analysis, Budapest |

The EnergyCity WebGIS immediately shows that almost half of the buildings (41%) in the area have an average value of heat loss. There are also 18% of buildings with very high heat loss and as already mentioned 10% of buildings with high heat loss. This means that 38% of the buildings have higher than average heat loss.

Regarding the map, two issues are important for future planed activities regarding hot spots. First and foremost is the percentage of the buildings in the red class and the second is the distribution of hot spots in the area, type of buildings and age of the building.

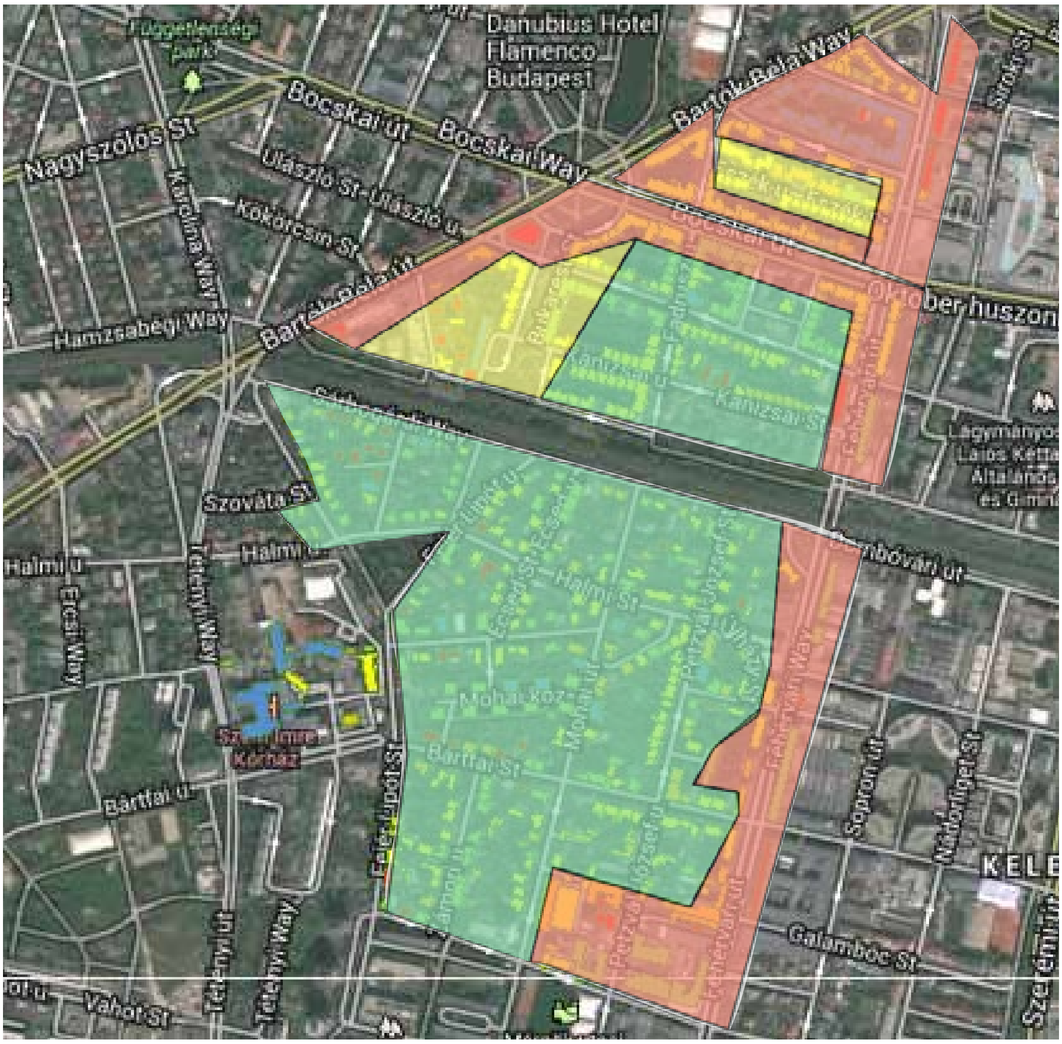
The red coloured buildings are hot spots representing around 18% of the building stock in the area. From the map we can notice that the locations of these hotspots are distributed around two major streets. If we investigate the data further, they show that most of these buildings were built in the same period. And also another issue appears that most of the red buildings are large multi-residential buildings, public buildings and production facilities. A cross-analysis has been carried out for a set of randomly selected buildings in order to measure the accuracy of the methodology (some examples can be seen in the next figure).

16 | Hotspots |

The SDSS allows city planners and decision makers to prepare a fuel poverty analysis in order to prepare targeted actions. Fuel poverty has also been analyzed for the Budapest test area. The result is presented In the following figure. In general, the wages in the area are above the Hungarian average. This district is close to the center and has a relatively significant amount of green space. However, next to the main road the value of the flats is lower because of the noise and pollution. This means that residents by the main roads are relatively poor (marked with red colour). In the area marked with green small multi-flat buildings are typically surrounded by a garden that makes the flats more expensive attracting people with higher living standard (in addition, the area is well located, close to the center). The yellow areas are in the middle, buildings are well located (less noise), but on the other hand the usual number of flats is higher.

The correlation between fuel poverty and poor energy quality is not clearly noticeable, although in the red areas there are definitely more buildings with high energy consumption than in the green and yellow areas. It is an important message to policy makers: these buildings suffer from fuel poverty the most, so energy efficiency supporting actions should have a priority here.

On the other had in the green areas there are many buildings with better than the average energy efficiency. Here less support is recommended.



17 | Budapest test area |

5.5. The Case of Bologna

The SDSS can contribute significantly to an energy efficiency action plan of the city. This will also be illustrated with the Bologna example.

The preparatory steps have been carried out within the project. The target of the Action Plan will be residential buildings within the sample area of the thermal survey, with a focus on buildings with the highest energy consumption.

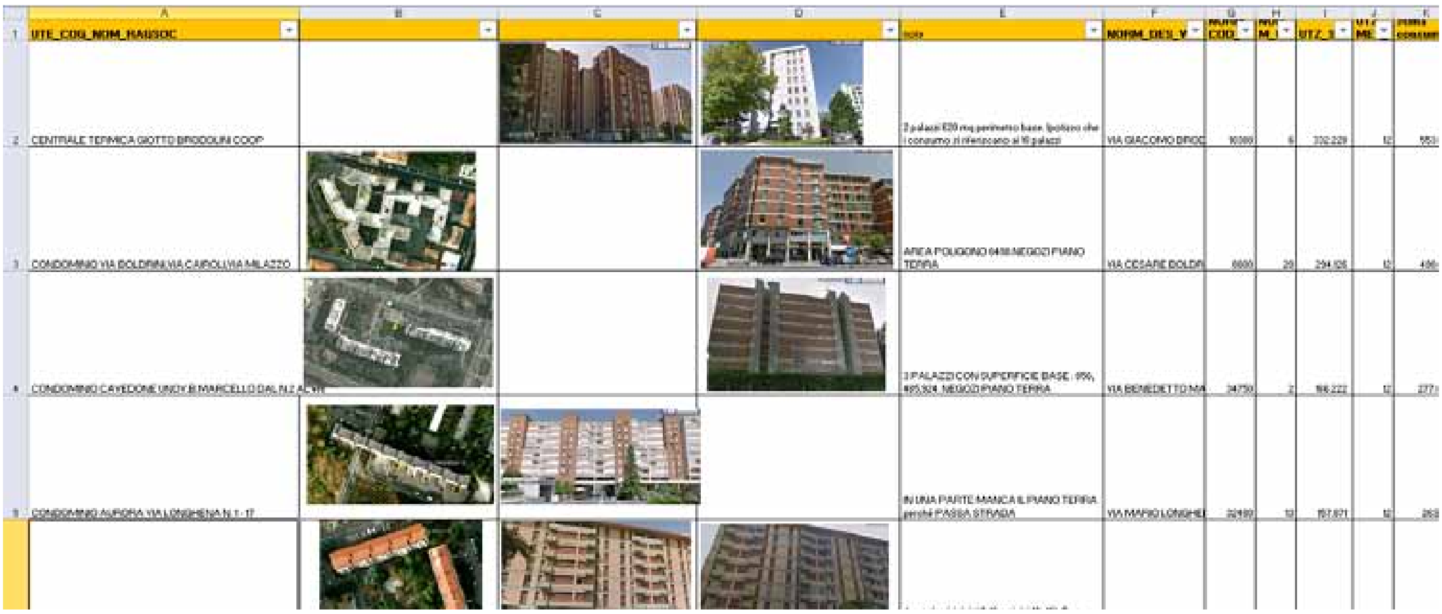
The reason for such a target is that Bologna's SEAP has already started a work on residential dwellings and has the aim to promote a campaign of diffuse energy efficient refurbishment in the domestic setor, helping the co-operation of families, financial institutions, technicians and ESCOs.

The idea is also to make a comparison of the results of potential savings given by the SDSS tool with evaluations carried out using the municipal databases (fuel consumption, basement area, gross volume, age/power of the heating plant) and a one-by-one visual analysis of the buildings through Google Maps street view (age of the building, status of conservation, roof type). This approach will allow to adopt a possible correction of SDSS results in order to extend the results of SDSS to a wider set of buildings.

A selection of buildings provided with centralised heating plants has been performed, looking for ones with the highest fuel consumption (natural gas).

A further analysis has been performed on a sample of these buildings, identifying those with the oldest heating plants. This subgroup of buildings has been identified in Google Maps.

A matching these buildings with the civic numbers of the buildings covered by the test area of the thermal survey has been carried out.



18 | Selection of buildings |

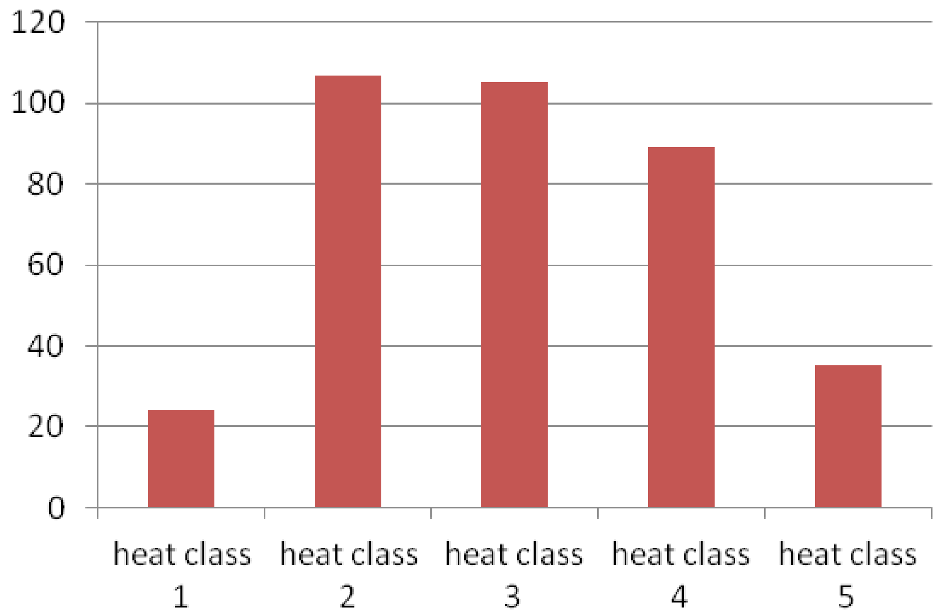
Within the test area of the thermal survey, one more more set of nearby residential buildings will be identified (provided with either centralised or autonomous heating plants), going through the SDSS and Google Maps. A subsample of buildings will be identified, having a natural gas consumption higher than 50,000 m3. A double analysis will be performed on the subsample of buildings, both using the SDSS tool and the bottom-

up analysis through the municipal databases and the visual survey of the buildings. The double analysis will yield possible measures and potential savings, which will be compared. The sets of buildings and suggested measures will become the Action Plan for Bologna.
The Municipal Administration intends to use the Action Plan as a reference tool to involve citizens in the implementation of energy efficiency measures, contributing to reach the goal of Bologna's SEAP. For the coming years, the Bologna SEAP gives energy efficiency of residential buildings the significant weight of 29% of the overall CO2 reduction by 2020. It is expected that the Action Plan may put the conditions to activate a substantial quota of energy savings.

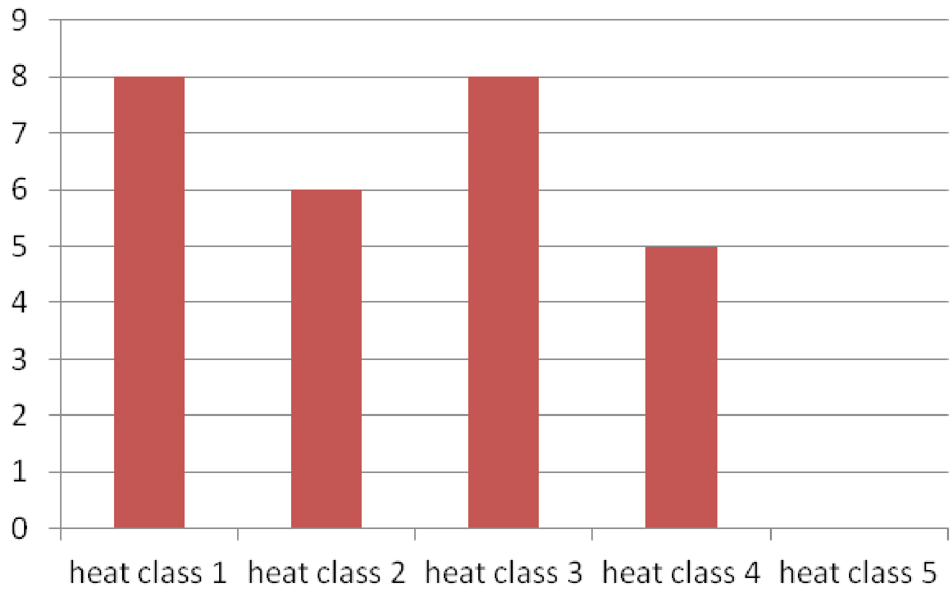
5.6. The Case of Prague

The case study focuses on the heat loss classification for a part of Prague 11 district. Heat loss classification was made for 360 buildings in chosen area. Almost all buildings are connected to the district heating system, several smaller houses in the south-east have a gas boilers. The heat in the district heating system is produced in the coal-fired electric power station in town Melnik 30 km far from Prague.
The particularity of the chosen area is that most buildings were built in the same period with similar technology. Some buildings have been renovated, so it would be possible to compare them with ones that were not. A carbon emission database was created based on the heat loss classification in Prague 11, for a selection of 27 buildings.

The figure below shows the distribution of heat loss classes for 360 buildings in chosen area. The 27 buildings were selected because there were other information sources available for cross-checking.

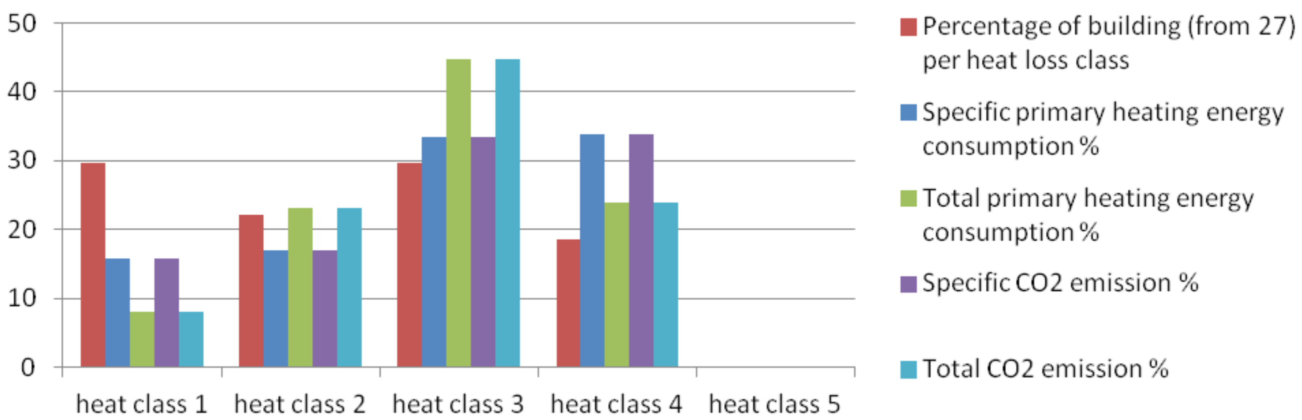


19 | Distribution of heat loss classes in the entire area - 360 buildings |



20 | Distribution of heat loss classes in 27 buildings under consideration |

During the carbon emissions analysis of Prague 11, the values for specific primary heating energy consumption, total primary heating energy consumption, specific CO2 emissions and total CO2 emissions were calculated and percentages of the values were determined. The results are shown in the next figure.

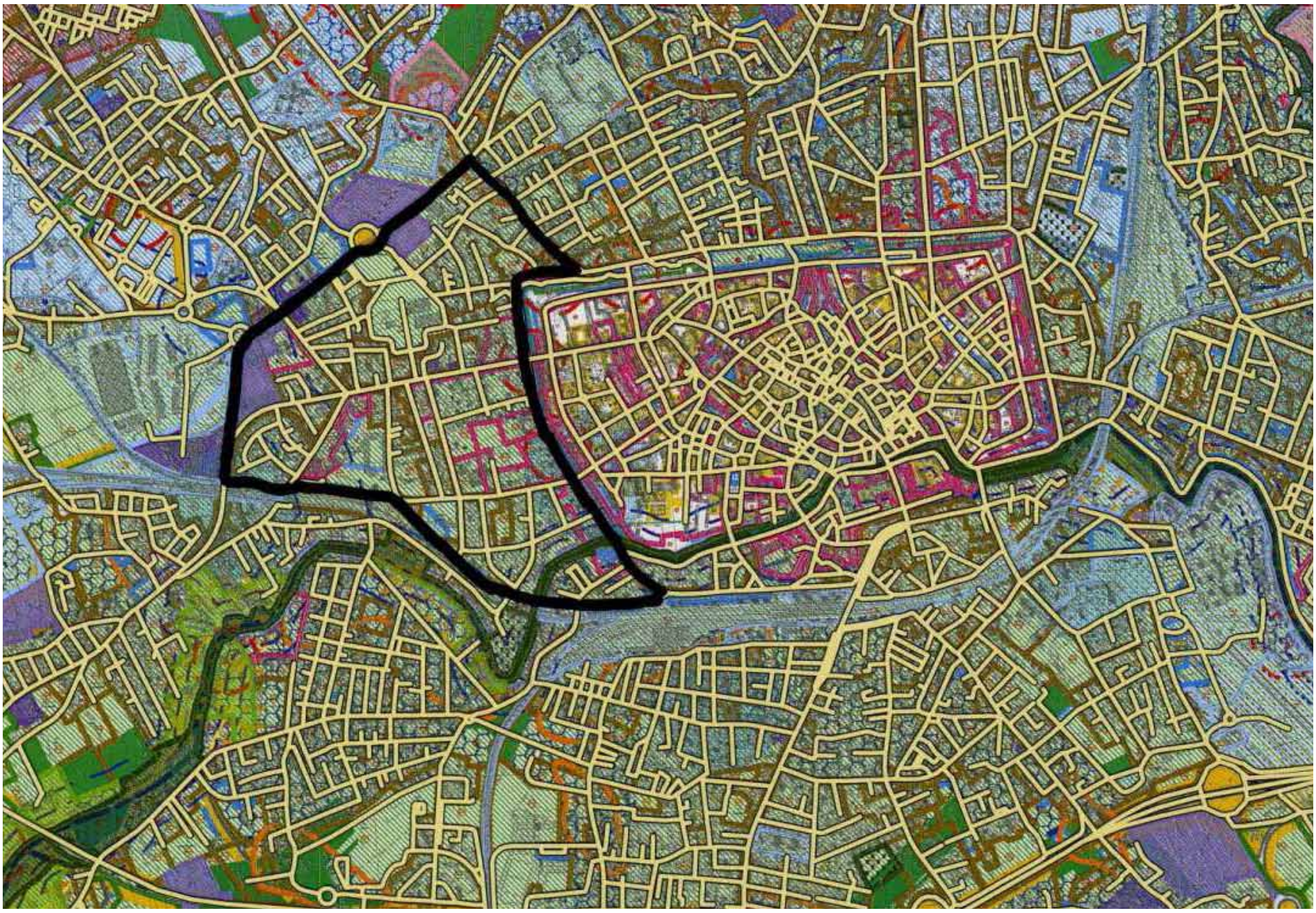


21 | Percentages of the energy consumption and emission values per heat loss class for 27 chosen buildings |

The majority of CO2 emissions is casued by the buildings in heat loss class 3 and 4. Return on Investment is fastest for heat loss class 5 and the decreasing specific CO2 emission in case of renovation. In addition, the assessment shows that complete renovations usually move the buildings to heat loss class 1 and partial renovations move the building to next better heat loss class.

5.7. The Case of Treviso

As with the other cities in the project, a smaller area in Treviso has been selected to carry out initial investigations. This area is known in the city as "Eden" - from the name of a theatre located in its centre which opened in 1910 - and is situated in the proximity of the western portion of the 16th century city walls. The figure below shows the location and extent of this test area.



22 | The city of Treviso |

From within the EnergyCity SDSS, a series of visual representations of critical areas in terms of energy consumptions and CO2 emissions has been obtained. These areas are displayed in maps with colour codes based on heat losses. Areas with high heat loss are represented as hot spots. Using the map window in the EnergyCity SDSS, a general view of the heat loss map of the Eden area in Treviso can be obtained. At first glance, it appears that the number of red coloured buildings – representing hot spots – is limited, representing around 10% of the total buildings. By looking at the map one can notice that the location of these hotspots is restricted to a central strip of the Eden area that runs from top to bottom with red buildings distributed evenly inside this area. What is striking is that to the East and West of this central stripe there are almost no hot spots. What is also particularly interesting is that a high number of these hotspots are buildings of a considerable size and, using the Google Street View functionality in the WebGIS, they appear to have been built very recently.

The cause of the high heat loss for these newly built buildings is therefore worth investigating to establish whether it is due to poor insulation standards or a high rate of occupancy and activity within the building that can cause a considerable increase of the overall temperature of the buildings. These buildings will be investigated, alongside the other hot spots in the Eden area with a deep energy audit by the municipality.

6. Technical Background

6.1. Data collection and processing

Data collection

For the creation of the heat loss maps for the cities involved in the project, an extensive set of digital data is required; among them, high resolution thermal imagery acquired by an infrared sensor installed on an aerial platform is the most important, but also additional digital data (multi and hyperspectral images, digital cartography with buildings attributes, digital elevation/surface models, atmospheric measurements and georeferenced ground surveys, etc.) are necessary to perform all the steps of processing necessary to correct thermal imagery and compute accurate surface temperatures.

In fact, thermal and hyperspectral aerial images, ground thermal images, GPS data and multi-spectral images from satellite platforms require different steps of processing in order to compute with suitable accuracy the mean roof surface temperature that will be used to estimate the energy performance of buildings and related CO_2 emissions through the application of energy models.

In EnergyCity, the National Institute of Oceanography and applied Geophysics (OGS) was responsible for aerial surveys, both thermal and hyperspectral; DICAM dealt instead with the collection of all the existing datasets supplied by the municipalities, and for the execution of thermal ground surveys simultaneously with the thermal flights.
Obtaining high quality aerial images depends on several factors, including cloud, snow, wind, and sun angle. Ideal conditions are clear skies and no strong winds that can cause upper air turbulence that makes difficult to maintain good direction.

Thermal surveys were carried out at night, this is because during the daytime sunlight (both direct and diffused) causes infrared reflections which may interfere with the radiation emitted from the target. Ideally the survey should be carried out in cold conditions. The colder the better, as the greater the difference between the exterior of the house and the outside air temperature, the more clearly the heat emission will be seen. Hyperspectral surveys (for the purpose of classification of the roof materials) were carried out during day. The optimum sun angle is between 25 degrees and 45 degrees above the horizon; angles above 30 degrees provide enough reflective light and minimize the effects of long shadows.

Thermal images have been acquired with a thermal infrared (IR) camera NEC TS9260. The camera has a spectral range of 8 – 13 μm and resolution of 640x480 pixels. The flight altitude was approximately 850 meters for each city and the speed of the plane was 110 kts.
Although infrared radiation is not detectable by the human eye, an IR camera can convert it to a visual image that despites thermal variations across an object of a scene. IR covers a portion of the electromagnetic spectrum from approximately 0.9 to 14 μm. IR is emitted by all objects at temperatures above zero and the amount of radiation increases with temperature.

Thermography is a type of imaging that is accomplished with an IR camera calibrated to display temperature values across an object or scene. Therefore, thermography allows to make measurements of the infrared radiation emitted or reflected by an object, and to transform them to a temperature.

Hyperspectral images have been acquired through the AISA system, capable of collecting data within a spectral range of 400 to 970 nm. The sensor can acquire any band combination ranging from a few multispectral bands to full hyperspectral data sets of 244 bands. The flight height was approximately 1250 meters for each city, the speed of the plane was 110 kts and the number of bands was set to 63.

The “hyper” in hyperspectral means “over” as in “too many” and refers to the large number of measured wavelength bands. Hyperspectral images are spectrally overdetermined, which means that they provide ample spectral information to identify and distinguish spectrally unique materials. Hyperspectral imagery provides the potential for more accurate and detailed information extraction with respect to any other type of remotely sensed data. Contemporary to thermal flight performed by OGS, some **ground surveys** were carried out for every city involved. This type of survey is divided into two phases (figure). Before the flight a set of about ten points on the ground is selected, in locations easily recognizable from aerial images and with homogeneous pavement materials. The geographic position of targets is computed with high accuracy using a GNSS dual frequency receiver (L1 + L2 - GPS + GLONASS) in combination with data from permanent GPS stations. In addition, a target of black electrical tape (with known emissivity) is applied just next to spots, in order to reach thermal equilibrium with the underlying pavements.

During the flight, once the target had reached the same temperature as the pavement, the DICAM team proceeded to measure both the atmospheric parameters and the apparent surface temperature of the ground for each of the points selected, using a thermal infrared camera (FLIR P620) with a spatial resolution of 640 x 480 pixels.

24 | Phases of the ground surveys |

Ground surveys performed during flight operations were used:

» to obtain surface temperature measurements in the area overflown by the aircraft much less influenced by the effects of the atmosphere, due to the short distance between the pavement to be measured and the infrared sensor (< 1,5 m); values obtained are used as ground truth to evaluate the accuracy of the atmospheric corrections (and the whole processing workflow) of thermal aerial images;

» to assess emissivity values for several existing ground pavements;

» to obtain atmospheric measurements of near-ground air temperature and relative humidity, that could be used as parameters in the radiometric processing of thermal aerial imagery and in the application of the energy building models;

It's important to underline that the GPS post-processing elaboration of the locations where ground surveys were carried out is essential; the assignation of absolute coordinates (in an adequate cartographic reference system) to the measured points permits to locate and recognize the same points on any raster or vector map containing the same area that will be implemented in the WebGIS decision support system (SDSS).

For the processing of all the data acquired and the implementation of the thermal images into the SDSS **a series of data supplied by the municipalities** are required, such as the digital cartography, the digital elevation model, the atmospheric observations at the time of the survey.

The **digital cartography** must provide, apart from the geometric properties of buildings (area, volume, orientation and position), a set of attributes related to their structural features, age of construction, type of use and to the characteristics of heating systems that are relevant to perform energy efficiency analysis; among them the function of the buildings, the number of floors, the dominant energy source, the construction period. In addition, the digital cartography will be the main layer in the Geographic Information System (SDSS), and therefore any other created or derived vector and raster map will be superimposed on it.

A high resolution **Digital Terrain/Surface Model** (DTM or DSM), in grid or TIN format, is instead required both for the orthorectification of aerial imagery (thermal and hyperspectral) and to derive some attributes of the buildings inside the test areas (e.g. heights) if not otherwise available. Finally it could be used in the application of heat balance models, to correct environmental parameters for the effect of elevation.

For the purposes of the project, **atmospheric measurements of near ground air conditions from meteorological networks** (or ground surveys) are required, while measurements of atmospheric profiles from radiosondes or rawinsondes are ancillary.

Measurements of near ground air temperature and relative humidity covering the time-span of the thermal surveys are of fundamental importance both for the application of the energy models (allowing to define the external environmental conditions that govern heat exchange from buildings and energetic balances of roof surfaces) and for the radiometric correction of the thermal imagery (permitting to define the physical characteristics of the first layer of the atmosphere). In the case in which no meteorological networks are operating in the urban test area, the required data could be derived from the measurements of atmospheric parameters carried out during the ground surveys mentioned before.
Measured values of temperature, humidity and pressure of the air column between the ground and the sensor at the time of thermal acquisitions is instead required to perform the correction of the thermal imagery for the atmospheric effects. For the computation of all the radiation factors involved in the sensor model that modify the radiance detected in infrared wavelengths by the thermal sensor, it is in fact necessary to supply the physical radiative model with the variation of several environmental parameters with altitude (or in alternative, if not available, the selection of a standardized atmospheric profile from a list representing several standard environments).

The recordings from GNSS permanent stations in proximity of test areas, with an appropriate sampling frequency (1”), are necessary primarily in order to perform the exterior orientation of thermal and hyperspectral images, of fundamental importance in the orthorectifying process; in fact they permits to compute with post processing techniques the accurate positions of the aircraft (and subsequentially the sensor) along the flight path during the acquisition of images. In addition, they are required to compute high-accuracy coordinates of the targets measured during ground surveys, allowing to identify them on the aerial infrared images and to compare the temperatures measured on the ground with those calculated from the thermal mosaics after the radiometric correction.

Finally, **very-high resolution satellite imagery** from the Worldview-2 sensor has been acquired in order to perform a pixel-based classification of the roof materials for the test area of Bologna, where the hyperspectral survey has not been carried out due to technical problems. The dataset, already georeferenced, is comprised of a panchromatic band (with a spatial resolution of 0,5 m) and eight multi-spectral bands (with a spatial resolution of 2 m) covering the spectral region of visible and near-infrared.

Contribution of the participating cities

For the selected test area building data were provided to feed the basic data load of the SDSS. In some cases, beside the available data at the city administration (height, main function, listed buildings, dominant energy source and brut floor area) external experts of the cities collected further information in order to calculate the Heat Loss Classes of individual buildings and the Pilot Area. The definition of relevant types of buildings comprised state of modernization, roof types and the detailed orientation of the buildings.
In Ludwigsburg the City administration contacted 100 house owners to inform about the research activities

and asked for their willingness in participating. The response rate was 15%.

The database also needs CO_2 emission factors. These are used to calculate emissions and heating costs. In order to provide normed values for the digital building dataset energy factors for gas, oil, pellets, wood-chips, night storage oven and district heating were provided.
On the same day of the thermal flights DICAM carried out ground surveys in the cities in order to underline GPS post processing and to obtain surface temperature measurements. The ground measuring activities were also supported by municipal partners.

Data processing

The main objective of all the steps of thermal image processing is to obtain a mean temperature value representative of the roof temperature for every building inside urban test areas so as to relate it - on the basis of building typology and energetic models - to the energy efficiency and CO_2 production of the entire building.
Thermal cameras aren't indeed non-contact thermometers; they measure the infrared radiation that the sensor receives, and through the internal correction model and the input of several parameters, compute a temperature value from this radiation on the basis of Planck's law.

The internal correction model of thermal cameras has been developed for building trade thermography applications, mainly ground-based, and therefore is too simplified to be successfully used in aerial analysis; in addition, to create maps of heat loss from infrared surveys, it is fundamental to create georeferenced mosaics of surface temperature with metric relevance.

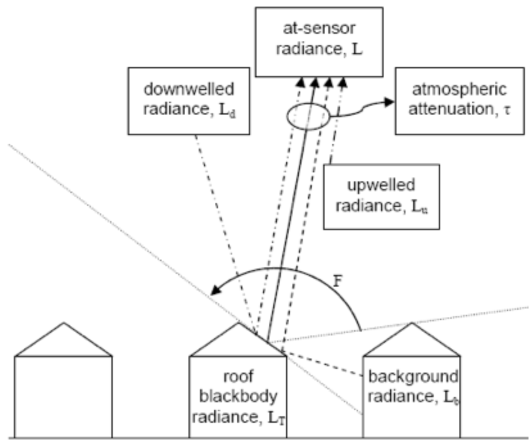
This chapter is focused on the sequence of processing phases necessary to transform all the sets of photograms acquired by the infrared sensor during the thermal surveys in georeferenced maps of surface temperature to be implemented into the SDSS, using all the datasets already collected and correcting the images for the effects of the atmosphere and for the characteristics of the surfaces laying on the ground.
In order to assess roof surface temperatures as close as possible to reality, it is in fact necessary to transform pseudo-temperature images acquired by the camera in radiance-at-sensor values, correct them for the effects of atmosphere, emissivity and acquisition geometry and, after implementing digital cartography data, compute temperature values representative of the roof for every single building.

The measurement scheme that illustrates radiation paths from different sources is schematized in the figure. The radiation that the infrared sensor measures is only in part emitted from the roof, as it is also composed by the radiation reflected from the roof and originated by the sky or the surroundings, and by the radiation emitted from the atmosphere; in addition the column of air between the ground and the aircraft, that is characterized by a transmittance value in thermal infrared wavelengths, absorbs a portion of this radiation attenuating the radiance that reaches the sensor.

The theoretical formula that describes the radiance reaching the sensor (sensor model) is:

$$L_S = \left[\varepsilon \cdot L_T + (1-\varepsilon) \cdot \left[F \cdot L_d + (1-F) \cdot L_b\right]\right] \cdot \tau + L_u$$

Where:
L_S = at-sensor radiance [W/m2sr]
L_T = roof blackbody radiance [W/m2sr]
L_d = downwelling radiance [W/m2sr]
L_b = average background radiance [W/m2sr]
L_u = upwelling radiance [W/m2sr]
ε = emissivity of the roof
t = transmittance of the atmosphere
F = Sky view factor of the roof



25 | Sensor model for thermal infrared camera in aerial surveys (source: D. Allinson) |

Considering the equation above, the average background radiance as well as the estimation of the Sky View Factor are very difficult to obtain, although a detailed 3D model of the buildings is available; even if it is an approximation, in some cases it is desirable to utilize a simplified equation.

The simplified sensor model, used for the radiometric processing of the thermal mosaics, is calculated using the above equation under the assumption that all the roofs are plane, horizontal and isolated, and thus neglecting the effects of the Sky View Factor (which is assumed to be equal to 1).

The reference formula used to derive the roof blackbody radiance is therefore:

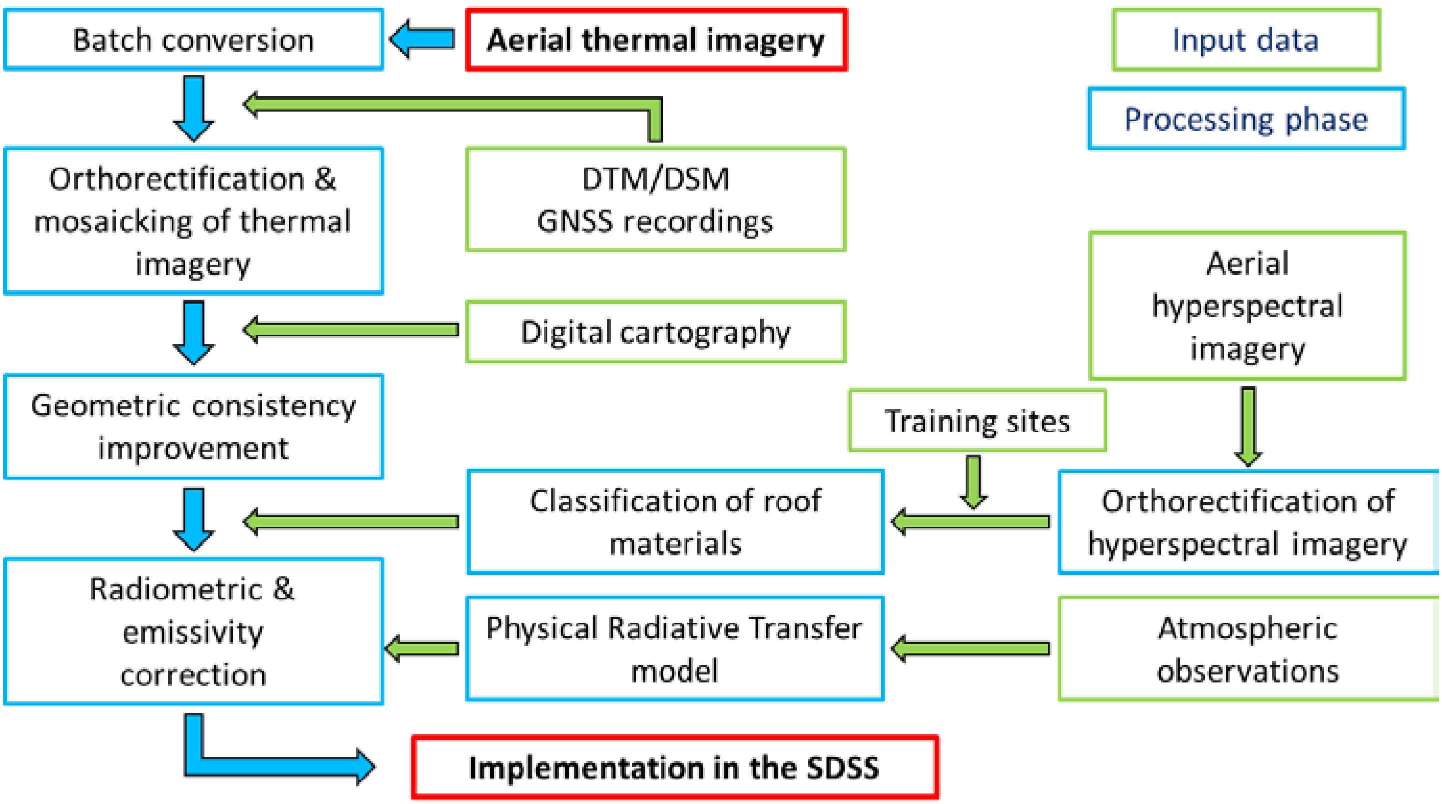
$$L_S = \left[\varepsilon \cdot L_T + (1-\varepsilon) \cdot L_d\right] \cdot \tau + L_u$$

Through the inversion of the previous equation it is possible to obtain a mosaic of roof blackbody radiance transforming the image of radiance-at-sensor using the following formula:

$$L_T = \frac{L_S - (1-\varepsilon) \cdot L_d - L_u}{\varepsilon \cdot \tau}$$

Finally, the surface temperature can be calculated from the blackbody radiance by means of the inversion of Planck's law in the spectral range of the infrared sensor. Of course the accuracy in the computation of all these radiation factors depends much on the data available for each city, and therefore the most suitable level of complexity can be chosen to meet the site-specific situation; the processing chain to derive the thermal maps can be adapted on the basis of availability and quality of data for every concrete situation.

The processing workflow can be schematized as follows (figure). All the processing phases and the intervening parameters will be described in next sub-chapters.

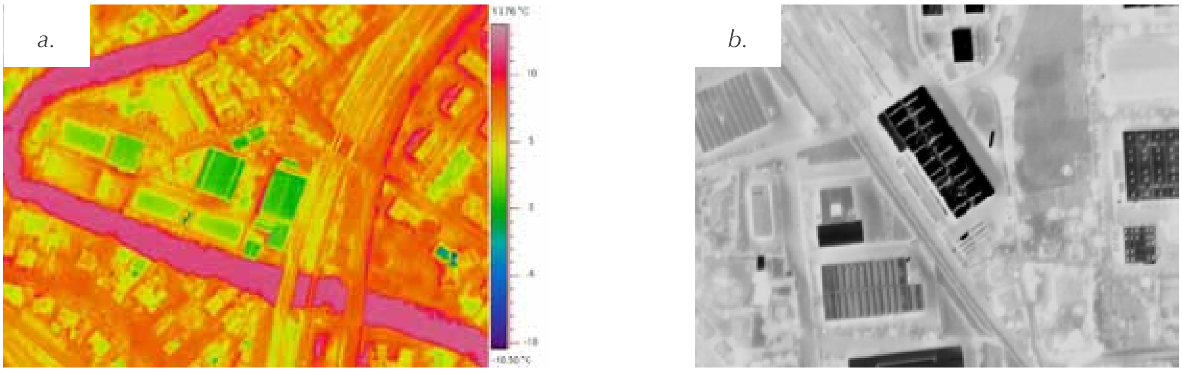


26 | Workflow for retrieving Roof Surface Temperature of buildings |

Batch conversion

The infrared camera used for the thermal survey stores images of apparent temperature, and enables only to export in standard image formats after applying a colour palette, useful for their visual interpretation; in this way it is not possible any operation of image-processing.

The first step consist, for each city, in the batch conversion of the entire set of thermal photograms in gray-level images of surface temperature (figure), which are subsequently transformed into images of at-sensor radiance through the application of Planck's law in the spectral range acquired by the sensor.



27 | (a) Thermal image with palette (b) Gray-level image of apparent temperature |

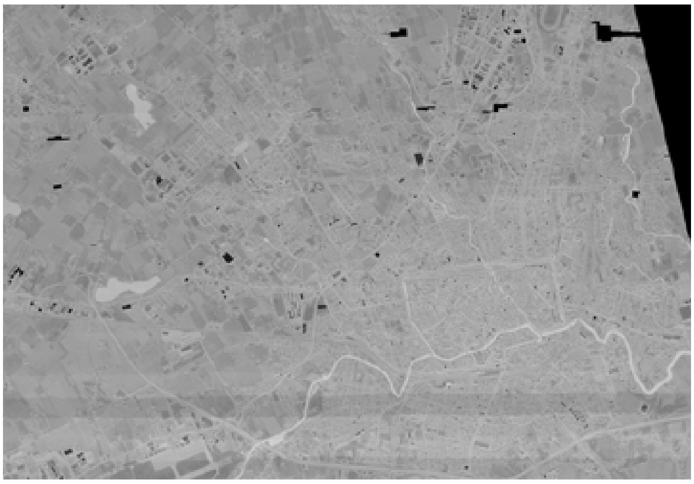
Orthorectification and mosaicking

After being acquired, single photograms are rectified – rectification is a process of transforming an uncorrected, raw image from an arbitrary coordinate system into a map projection coordinate system.

This process requires the identification of a large number of points called tie points that are common to adjacent photograms.

Aerial mosaics are constructed from sets of individual adjoining rectified photograms. Typically, the outer edge of the photo coverage of each print is trimmed back to a selected match line, and the photos assembled by carefully matching ground detail along the match line.

Because a single rectified photo is limited in area, groups of photos are combined into mosaics to provide the aerial picture. Mosaics are of principal use for presenting synoptic views of a relatively large area. The image above shows the thermal mosaic of apparent surface temperature for the test area in Treviso.



28 | Thermal mosaic for the city of Treviso (acquired on 19/02/2011) |

Application of the physical radiative model

The atmosphere alters reflected and emitted radiance by absorbing, emitting and scattering radiation; in order to enhance the spectral characteristics of the observed surfaces and to mitigate the dependency of the retrieved radiometric values to the particular setting of the image acquisition, an atmospheric correction of the airborne data (both thermal and hyperspectral) is to be undertaken. This correction can be achieved by two different approaches: either by physical modelling of the radiative transfer process along the path between the sensor and the surface or by an empirical calibration through field data. The physical approach consists in a numerical solution of the radiative transfer equation and the computation of the atmospheric transmittance, the upwelling and downwelling radiance.

For the EnergyCity project, the most widely used physical radiative transfer code, Modtran (MODerate resolution atmospheric TRANsmission) 5.2.1, which covers the thermal infrared region with a very high spectral resolution (up to 0.2 cm-1), is used for the calculation of all the atmospheric properties forming part of the sensor model.

A proper parameterization of the model requires the following inputs:

» acquisition geometry (solar and sensor azimuth and elevation)

» sensor characteristics (spectral response function)

» target properties (bidirectional reflectance function)

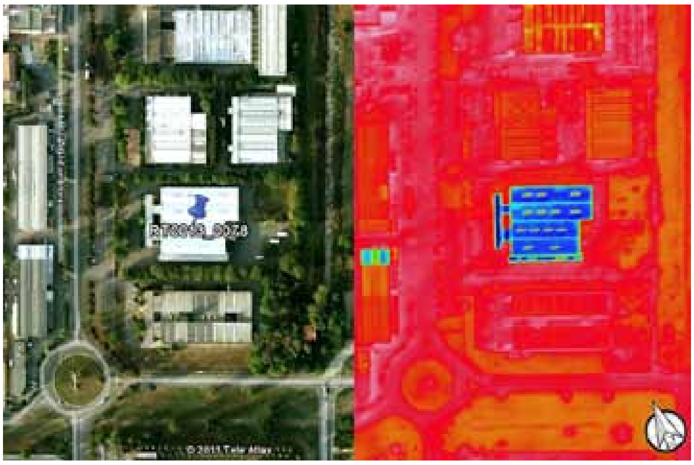
» atmospheric profile (gas abundance, pressure and temperature)

» aerosol model (particulate composition and abundance)

Of course some approximations are acceptable when some data are missing. For instance, non-lambertian behavior of surfaces may be neglected by assuming a constant BRDF function, or standard atmospheric profiles of temperature, pressure and humidity can be used as inputs.

Emissivity correction

The emissivity, and in particular the spectral emissivity referred to the thermal infrared region of the electromagnetic spectrum, it's a key factor in computation of surface temperatures of buildings roofs and of any object on the ground. It is worth highlighting that a thermal camera doesn't allow deriving the temperature and emissivity of objects simultaneously, but rather calculates the temperature on the basis of the emissivity value assigned to them. Thus variations in the emissivity value of a surface induce strong variations in the temperature calculated by the camera; this can be problematic especially for roofs with non-oxidized metal covering that usually have a low emissivity value and can produce anomalies on thermal images (the measured radiation is mostly reflected by the surface, as shown in the figure below).



29 | Effects of roofs with high reflectance on thermal images |

In the EnergyCity project, to derive an emissivity value for every pixel of the thermal mosaics a supervised classification of the hyperspectral images (or the high resolution satellite image for the case of Bologna) has been performed (figure) by using a pixel-based approach.

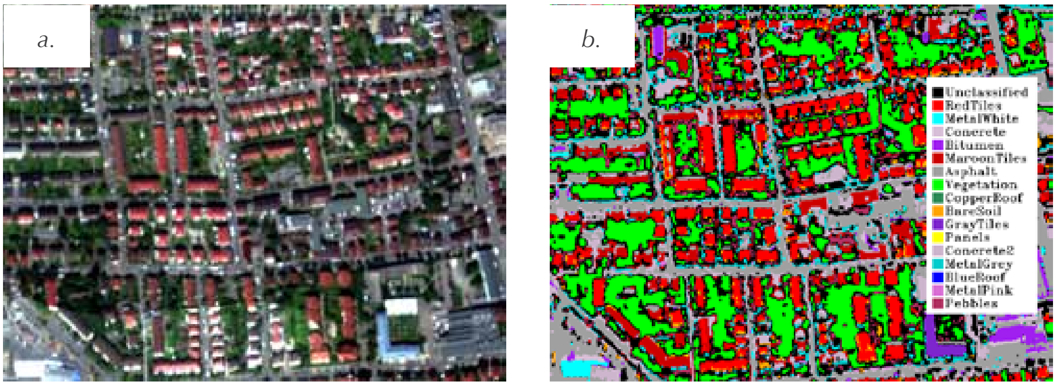
The algorithm used for the pixel-based classification of hyperspectral mosaics is the Spectral Angle Mapper (SAM) that seems to be the most suitable for identification of roof materials because it minimizes the influence of lighting and shadows on the scene.

For each city, to select the number and the type of classes to be used for the classification, a selection of buildings with the prevalent cover materials and representative of the test area have been provided by each municipality, and subsequently used to define the set of training sites. The classification of roof materials is then converted in an emissivity map (referred to the spectral range acquired by the infrared sensor) using for each class an emissivity value derived from tabular data.

Roof surface temperature evaluation

The mosaics of at-sensor radiance and emissivity are then co-registered, and thus using all the factors appearing in the reference formula described above it is possible to solve the sensor model with the calculation of the black-body radiance for each pixel of the thermal image. This value can be easily transformed in corrected surface temperature by using the inversion of Planck's Law in the thermal infrared spectral range.
For the application of the energetic building model it's necessary to retrieve for each building a single temperature value that can represent the thermal behaviour of its roof; after the superimposition of the digital cartography on the temperature map it's therefore appropriate to operate a spatial averaging of the digital values inside the buildings polygons.

Actually some geometric errors are inevitable, and simply averaging pixels into the contours of buildings it's possible to include some pixels laying on other objects on the ground, influencing the final surface temperature value to assign to the building's roof; some strategies were developed for this purpose. Furthermore, to avoid the sampling of pixels with excessively high (e.g. fireplaces, chimneys) or low (e.g. highly reflective metal surfaces) temperatures, a preventive thresholding of the corrected temperature map is performed excluding the extreme values.



30 | (a) hyper-spectral mosaic (b) pixel-based classification |

6.2. The heat loss model

Among the collected (and available) data the outputs from the aerial survey and data processing is the only dataset that provides information about every single building inside the test areas. It is the quickest and most efficient way of collecting building-related data providing energy related information about the building stock. However the average temperature of the roofs is just one element from the heat balance of a building, therefore during the application of the proposed model users have to be aware of the limitations of the methodology.

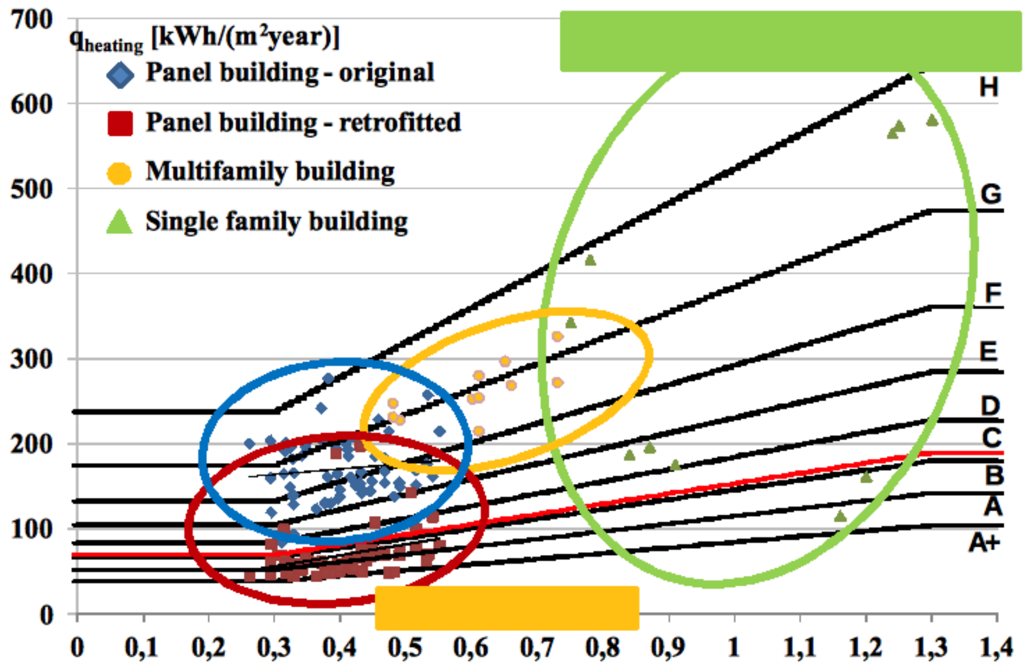
The heat loss of the building cannot be calculated from the roof temperature (Allinson, 20071) in an accurate way, particularly for buildings with unheated roofs, therefore a temporary stochastic approach has been applied in the model.

The methodology is based on a simplified assumption that the buildings with colder roofs generally belong to better insulated buildings, whilst buildings with warm roofs are poorly insulated with higher probability.

Please note that there are possibilities to improve the accuracy in the future by collecting other types of energy related information about the buildings on city level with quick techniques, thus the model of the Energy-City project should be considered as an intermediate phase of a longer-term development.

Besides the roof temperatures, another important parameter can be determined using digital cartography and aerial surveys: it is the surface-to-volume ratio. This parameter strongly influences the heat loss of a building. If a building has double exposed surface per one cubic meter volume, the transmission heat loss will be double considering the same building structures. It also correlates to the size of the buildings: larger buildings have generally lower surface-to-volumes ratios than small buildings. Figure shows an example for a set of buildings in Budapest. In the diagram every spot represents one building. The specific heating energy consumption of the buildings were determined by a detailed methodology (based on real consumptions or building energy certificates) are presented in function of the surface-to-volume ratio. As the figure proves the largest buildings that are the so-called panel buildings (also called housing estates – buildings built with pre-fabricated technology built in the seventies and eighties – very typical for Eastern-Europe) are characterized by the lowest surface-to-volume ratios, whilst for the small buildings (family houses) this value is high. It is also clear from the graph that buildings with low surface-to-volume ratio consume less than those with high values. Letters from A+ to H correspond to the energy efficiency values of the Hungarian building energy certification system (not used in the model).

Based on such preliminary studies the realistic ranges for specific heating energy consumptions were determined in function of the A/V values. For example for the Hungarian large panel buildings, the model allows variations of the final heating energy between 40 and 300 kWh/m2year only. For family buildings with A/V above 1.3 m2/m3 the allowed range is 100-650 kWh/m2year. It is just the principle, the model behind the SDSS is a bit more sophisticated.

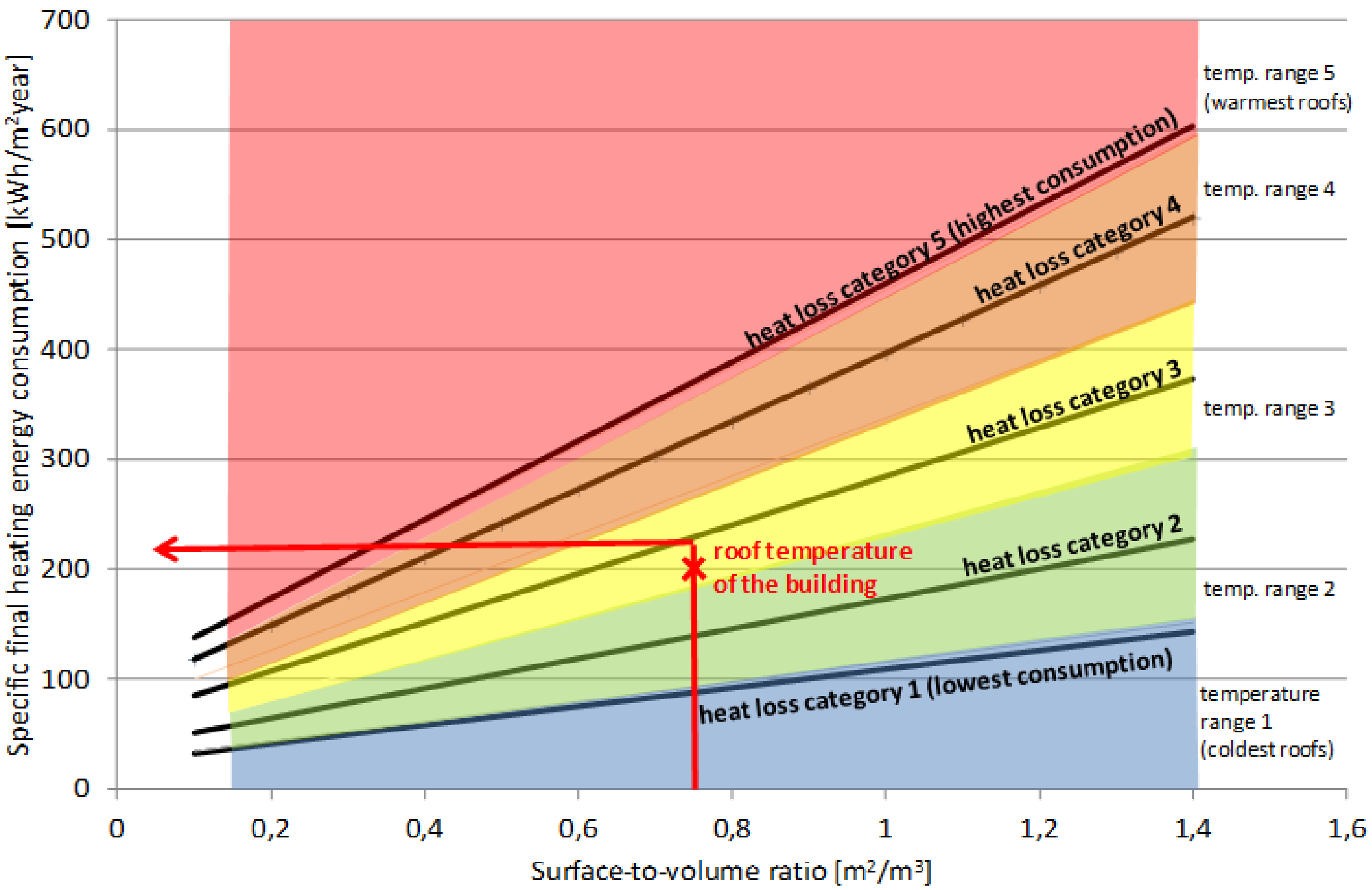


31 | Specific final heating consumption of buildings in Budapest in function of the surface-to-volume ratio for the determination of probabilistic consumption ranges |

The realistic ranges have been determined based on datasets from accurate sources for Munich and Budapest. For the rest of the test cities such data were not available, therefore the ranges have been transformed from the results of Budapest and Munich taking into account the differences in the local climate (heating degree days) and in the building traditions (usual levels of energy efficiency in the country).

It also means with high probability that a roof with the same heat loss per square meter (or temperature) corresponds to a higher specific energy consumption for a family building than for a large multi-flat building.

After determining the realistic ranges for each city the minimum, maximum and mean values of the ranges were adjusted to the lowest, mean and highest roof temperatures in function of the A/V. The probabilistic consumption range was classified into 5 sub-ranges marked with different background colours in the figure. The estimated consumption is calculated from the mean values of the ranges represented by the solid lines (except for the lowest and highest consumption ranges). Note that the parameters of the horizontal and the vertical axis are identical to the one in the figure. It is also important to highlight that the heat loss categories are determined independently for each city. A building of category means 'close to the city average', with other words a relative scale is used in the categorisation. Similarly, buildings of the same heat loss class with different A/V values in the same city would have different specific energy consumption. If buildings from different cities or different A/V values are to be compared the energy consumption and CO_2 emission values should be regarded instead of heat loss classes.



32 | The principle of the heat loss model for the case of Budapest |

From the specific consumption obtained from the diagram, the total final heating energy of the entire building can be calculated by simply multiplying it with the total net floor area estimated from the covered ground surface from the digital cartography and the number of floors. The number of floors comes from the digital building database provided by the participating municipalities.

The primary energy (without the consumption of supplementary electric appliances) is calculated as the product of the final heating energy consumption and the primary energy factor of the used fuel for heating. At the moment the fuel is selected manually in the SDSS, but it is possible to integrate a fuel database into the system if data are available. The primary energy factors are given by the national legislations based on the energy performance of buildings directive.

Similarly, the CO_2 emission is calculated as the product of the final heating energy consumption and the CO_2 emission factors obtained from national legislative documents.

As described, the model has certain limitations influencing the accuracy of the results obtainable from the SDSS. The model is adjusted to the realistic consumption levels, therefore its application is recommended for decision making on district level and not on the level of single buildings. Analysis of single buildings with the SDSS can highlight hot-spots that are probably worth for further deeper investigation, but the method cannot substitute a detailed energy audit or certification.

NOTE

[1] David Allinson: Evaluation of aerial thermography to discriminate loft insulation in residential housing; Thesis submitted to the University of Nottingham for the degree of Doctor of Philosophy, May 2007

7. The partnership - who to contact?

The partnership in EnergyCity includes a well-balanced mixture of partners coming from two main sectors, city authorities on one side and research institutions on the other. Together, they represent varied views across a range of stakeholders and interests and provide competent knowledge and experience in the field of energy efficiency, renewable energy sources and geographic intelligence, especially with regards to urban environments and infrastructures in Central Europe. EnergyCity partners from cities or local authorities are well known for their commitment and motivation towards the improvement of their urban environment and have all joined relevant transnational or national initiatives in the fields of energy efficiency or sustainable living. The academic or research institutions in the partnership play both a leading and scientific role and will be key in helping the cities and local authorities in the project acquire the level of geographic intelligence and technical knowledge that is needed to support action planning against soaring CO_2 emission levels and energy usage.

33 | Technical meeting in Verona, 2011 |

34 | Transnational project meeting in Ludwigsburg, 2011 |

HUNGARY (coordination)

Budapest University of Technology and Economics (BME)

The Budapest University of Technology and Economics (BME) was founded in 1782, and it was the first institute in Europe to train engineers at university level. BME, as a prestigious Hungarian higher education institute is committed to differentiated, multilevel, high-standard education, founded on intensive basic training, research, development and innovation, and scientific qualification in technical and natural sciences and in certain fields of economic and social sciences.

The major research fields of the Department of Environmental Economics are environmental and resource economics, environmental management and policy, environmentally sound material and energy management, cost-effective studying of energy and climate policy, waste management and recycling, environmental management schemes (EMAS, ISO14001), sustainable transport and international environmental cooperation. The Department has an extensive background in transnational research projects (FP7, Central Europe, IEE, SEE, ESPON, Grundtvig).

Role in EnergyCity: In the EnergyCity project BME is the lead partner and its activities include: Project management and coordination, expertise of building energetics and energy policy.
More info and contact: www.bme.hu, http://kornygazd.bme.hu/, kornygzd@eik.bme.hu

AUSTRIA

Center of Excellence for Renewable Energy, Energy Efficiency and Environment (CERE)

CERE is a network of experts and acts world-wide in an interdisciplinary and multicultural way. It links professional competence, know-how and the most up-to-date technologies in the areas of renewable energy, energy efficiency and environmental technology. Since 1998, in cooperation with its member companies, CERE identifies and realizes transnational and trans-regional projects, be they part of international support programmes or independently financed. As a non-profit organization, CERE provides its members with the structural environment necessary in order to ensure the formal requirements for successful project development. CERE also supplies it's members with a platform for communication, information, transfer of knowledge and exchange of experience as well as for cross-selling.

Role in EnergyCity: CERE has an important role in the closing phase of the project as a responsible for the assessment of results and the development of a common transnational strategy.
More info and contact: www.cere.com, bachler@cere.com

CZECH REPUBLIC

Prague 11 Metropolitan District

Prague 11 represents one of the twenty-two quarters of the Capital of Prague. The administration of the quarter Prague 11 belongs to the system of the independent administration and action of the Capital Prague. As a public authority, Prague 11 strives to engage with stakeholders and citizens, understand their needs and expectations, build effective relationships with individuals, groups and organisations, influence others to take a positive approach to equality and diversity.

Role in EnergyCity: Prague 11 is responsible for the actions related to the city of Prague 11: review of existing data, local data collection, local pilot application of the SDSS, local and regional communication and dissemination actions.
More info and contact: www.praha11.cz, kuba.jezek@gmail.com

GERMANY

City of Ludwigsburg

The City of Ludwigsburg has a long standing experience in the following fields: geospatial and 3D field, webportal virtual City-atlas (internet info system, www.ludwigsburg.de), total energy concept (part thermal, traffic and electricity), energy/ rehabilitation/EU projects. The City organizes annual "energy weeks" with the involvement of the general public and has set up LEA (Ludwigsburg Enercy Agency), to offer building and energy advisory service. The City has also opened a new “department of sustainable urban development”, section-department, directly dedicated to the mayor, so the importance of sustainability is visible. It is also participating to the “European Energy Award”, a certification procedure with which the climate protection activities of the local authority are valued, planned and checked to identify potentials of climate protection. Ludwigsburg is involved in the setting up of a competence centre for energy, climate protection and eco-design, a network of different competences and actors in the area of energy saving, renewable energies, energy efficiency and eco-design. It is a member of Climate Alliance (Europe’s largest city network for climate protection which aims for the preservation of the global climate).

Role in EnergyCity: City of Ludwigsburg is responsible for the actions related to the city of Ludwigsburg: review of existing data, local data collection, local pilot application of the SDSS, local and regional communication and dissemination actions.
More info and contact: www.ludwigsburg.de, t.grossmann@ludwigsburg.de

City of Munich, Department of Health and Environment

Landeshauptstadt
München
Referat für Gesundheit
und Umwelt

The Department of Health and Environment’s “Bauzentrum” offers professional energy-consulting for the citizens of Munich. The Department acted as project partner in several cooperation projects with special attention on Energy and Climate Protection. The City of Munich is one of the first cities to sign the Covenant of Mayors and is a member of the EUROCITIES network. Munich started its integrated climate protection programme called the Sustainable Energy Action Plan. Over the recent years, the Department has built up considerable expertise in developing an environment management information system. Since the beginning of the World Wide Web, the department uses this medium for the dissemination of environmental information, a task which gains enormous importance under the obligations imposed by the principles of good governance. Yearly standardized monitoring of local CO_2-emissions and detailed CO_2- monitoring on a two-year basis are performed by the Department of Health and Environment.

Role in EnergyCity: City of Munich, Department of Health and Environment is responsible for the actions related to the city of Munich: review of existing data, local data collection, local pilot application of the SDSS, local and regional communication and dissemination actions.
More info and contact: www.muenchen.de, gube.rgu@muenchen.de

ITALY

Veneto Energy Consortium (CEV)

Consorzio CeV
Energia al servizio dell'Ente

The Veneto Energy Consortium has consolidated experience in the coordination of activities at national level amongst its over 900 associated public authorities. Its know-how is in the sourcing and delivery of energy from renewable sources and providing advice on energy saving, sustainability and green energy. CEV is carrying out a series of ambitious projects in Italy for its associated local authorities, amongst them the project "1000 Photovoltaics roofs", which aims at installing photovoltaic panels on the school roofs of the associated authorities without any financial contribution from the schools.

Role in EnergyCity: Among other tasks CEV is responsible for the SDSS software development and for the organization of the final conference. CEV also manages the actions related to the city of Treviso.
More info and contact: www.consorziocev.it, bgrimani@consorziocev.it

Comune di Bologna

COMUNE DI BOLOGNA

The Municipality plays a leading role in national environmental policies and has frequently received international acknowledgement for its achievements. The Environmental Quality Unit works actively with other departments towards the goal of urban sustainability. Bologna is a founder member of ICLEI, International Council for Local Environmental Initiatives (since 1993) and in 1994 adopted The Aalborg Charter. Currently main activities are: Environmental impact assessment, with specific reference to the regional law on Environmental Impact Assessment (VIA); Analysis and monitoring of the air pollution sources and effects on the environment and human health, with specific reference to atmospheric, acoustic and electromagnetic aspects. Implementation of the Municipality Energy Program. Covenant of Mayor. Elaboration and management of environmental dissemination projects. In the field of RES and RUE the Environmental Unit participated in several European Project since 2004.

Role in EnergyCity: Comune di Bologna is the coordinator of the municipal pilot actions demonstrating the application possibilities of the spatial decision support system. It is also responsible for the actions related to the city of Bologna: review of existing data, local data collection, local pilot application of the SDSS, local and regional communication and dissemination actions.
More info and contact: www.comune.bologna.it, francesco.tutino@comune.bologna.it

Alma Mater Studiorum University of Bologna, Department of Civil, Chemical, Environmental and Materials Engineering (DICAM)

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

DICAM is the Department of Civil Engineering, Chemistry, Environmental and Materials Engineering of the School of Architecture of the University of Bologna, recognized as the oldest University in the Western world. Today the University of Bologna boasts over 100,000 active students and is ranked in the top 200 Universities in the world. The Department is involved in a large number of European research projects, national and international, and has a great asset of contracts and agreements with public and private entities. The research group for EnergyCity pertains to the Area of Geomatics, under the responsibility of Prof. Gabriele Bitelli, Professor, Coordinator of the Master of Science in Building Engineering and Urban Systems and National coordinator of University Professors of Geomatics. The unit is equipped with a laboratory with modern equipment hardware and software in all fields of Geomatics and Surveying: state of the art software systems for satellite remote sensing and GIS applications, laser scanning of different types, advanced digital photogrammetric systems, classical and modern high precision surveying and geodetic instrumentation, GNSS systems in a variety of configurations, thermal camera, etc.

Role in EnergyCity: DICAM is the coordinator of the data collection and processing works providing the inputs for the spatial decision support systems.
More info and contact: www.dicam.unibo.it, gabriele.bitelli@unibo.it

National Institute of Oceanography and Experimental Geophysics (OGS)

The National Institute of Oceanography and Experimental Geophysics is a research institute financed by the Italian Ministry of Universities and Research, whose fields of research are: geology, geophysics, oceanography, biology. All the activities are carried out by five departments (Geophysics of the Lithosphere, Oceanography, Seismology, Marine Technology and Research, Marine Biology). OGS is concerned with transferring the results of its research activities to industry, collaborates with scientists from other institutions and establishes partnerships with industrial research centers. The CARS project unit (CArtography and Remote Sensing, part of the Geophysics of the Lithosphere Department) specifically operates in the field of remote sensing. Its main activities are laser-scanning, hyperspectral data and thermal data acquisition, processing and interpretation.

Role in EnergyCity: OGS performs the flights, the aerial data collections and a part of the data processing.
More info and contact: www.ogstrieste.it, rblanos@ogs.trieste.it

SLOVENIA

Energy Agency of Savinjska, Saleska and Koroska Region (KSSENA)

KSSENA was established in the framework of Establishment of local or regional energy Agencies within the European programme Intelligent Energy Europe. KSSENA is an expert organization specialized in the field of energetics, with the emphasis on RES and RUE, and project management. Activities carried out in KSSENA are: energy concepts, energy management, coordination and realization of national and EU project, activities for private sector, cooperation with national and European partners, communication with public, educational and other events.

KSSENA promotes energy efficiency, rational use of energy, company, SMEs, industrial undertaking projects including activities on the field of geothermal, biomass, biogas, wind and hydro energy, solar system and PV, renewable energy sources, rational use of energy, sustainable development, public lighting and transport, sustainable development, biodiesel and implementation of biogas into existing and potential new cogeneration systems.

KSSENA is coordinator of local management for companies and SMEs who want to collaborate in fostering energy efficiency projects in companies and enterprises. KSSENA assists local companies and SMEs for the purpose of rational use of energy projects.

Role in EnergyCity: KSSENA is responsible for the actions related to the city of Velenje: review of existing data, local data collection, local pilot application of the SDSS, local and regional communication and dissemination actions.
More info and contact: www.kssena.si, gregor.tepez@kssena.velenje.eu

8. How to get more information?

General information and contact

Project website:
www.energycity2013.eu

E-mail:
energycity@energycity2013.eu

CENTRAL EUROPE programme:
www.central2013.eu

For further contact details see chapter:
7. The partnership - who to contact?

Interesting documents

Newsletters in six languages (CZ, DE, EN, HU, IT, SI):
www.energycity2013.eu/pages/media/newsletter.php

Presentations of the final conference (Brussels, 2013):
www.energycity2013.eu/pages/project/events/final-conference.php

Presentations and papers of the mid-term conference (Debrecen, 2012):
www.energycity2013.eu/pages/project/events/mid-term-conference.php

More publications:
www.energycity2013.eu/pages/media/publications.php

Further relevant pages

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