European Commission

JRC TECHNICAL REPORTS

European Regional Energy Balance and Innovation Landscape (EREBILAND) - Energy demand of buildings

Deliverable 4: Case Studies of Optimisation

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2016

JRC Science Hub
https://ec.europa.eu/jrc

JRC104326

ISBN 978-92-79-64400-9 (PDF)

doi:10.2791/462472 (online)

How to cite: Baranzelli C, Aurambout J, Lavalle C. European Regional Energy Balance and Innovation Landscape (EREBILAND) - Energy demand of buildings - Deliverable 4: Case Studies of Optimisation; doi:10.2791/462472

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Abstract

The Exploratory Project EREBILAND (European Regional Energy Balance and Innovation Landscape) aims at supporting efficient patterns of regional energy supply and demand in Europe. Integration of spatial scales, from EU-wide to regional or local, and a cross-sector approach, are at the core of the project.

Energy targets are set at European level, but their realisation requires an implementation strategy that is tailored at EU Member States and regional level. National and regional specificities have to be taken on board when defining the priority of intervention for different sectors, from restructuring the energy sector to setting up efficiency targets for different categories of energy users.

The purpose of the EREBILAND project is to:

- provide an overview of the current trends of regional energy production and consumption patterns, and
- link these patterns to the structural characteristics of the regions, among which: population density and urbanisation trends, development of different economic sectors, and availability of resources and technological infrastructure.

Energy spent in buildings represents a large share of the overall energy consumption in the EU-28 (40% of total final energy consumption and around 55% of electricity consumption in 2012). The consumption depends on the functional and structural characteristics of buildings. It is also influenced by other factors such as location and climate.

This document describes a methodological approach developed as part of the EREBILAND project to estimate the energy demand of buildings at the local scale. It also provides and update on datasets compiled as part of the project and presents provisional results for two regional case-studies in Italy and the Netherlands.

1 Introduction

The EREBILAND (European Regional Energy Balance and Innovation Landscape) project aims at supporting efficient patterns of regional energy supply and demand in the EU. The issue of energy scarcity and efficient use of available resources is intrinsically of a multi-disciplinary and territorial nature: integration of spatial scales, from EU-wide to regional or local, and a cross-sector approach, are at the core of the project.

Energy targets are set at EU level, but their realisation requires an implementation strategy that is tailored at EU Member States and regional level. National and regional specifics have to be taken on board when defining the priority of intervention for different sectors, from restructuring the energy sector to setting up efficiency targets for different categories of energy users.

Energy spent in buildings represents a large share of the overall energy consumption in the EU-28 (40% of total final energy consumption and around 55% of electricity consumption in 2012). The consumption depends on the functional and structural characteristics of buildings. It is also influenced by other factors such as location and climate.

A detailed evaluation of the energy performance of buildings therefore requires knowledge of a number of parameters:

- Use of the building (residential, industrial, commercial or other)
- Building/dwelling characteristics (size, age, typology, household structure);
- Structural details (construction materials, renewal rate, certifications, etc.)
- Energy-related technological details (including for the production of energy)
- Climate and geographical location.

The availability of accurate and precise information on the status of buildings is of paramount importance to evaluate the energy performance of existing and new edifices and to assess the costs of effective improvements in terms of energy savings and production. The collection of such information for the review of the Energy Performance Building Directive (EPBD) is particularly challenging, since high spatial accuracy, at the level of single buildings, has to be achieved for all EU Member States (e.g. for all cities and towns in 28 Countries).

Recently (see ODYSSEE-MURE project at http://www.odyssee-mure.eu/) an analysis of trends in energy use and energy efficiency and the use of renewable energy for residential buildings (i.e. households) and non- residential buildings (i.e. service or tertiary sector) has been performed on the basis of data aggregated at National level including an exhaustive range of indicators, such as for example:

- Energy consumption (e.g. per dwelling, m^2, employee);
- Heating-cooling energy consumption
- Energy efficiency index and specific measures

Despite this wealth of information, it is still not possible to perform a detailed evaluation of the need and of the cost-effectiveness of measures whose implementation would require more detailed information at municipal or neighbourhood level, and – to evaluate costs and impacts – at level of single building. Such a detailed level of analysis would in turn help to identify areas (e.g. cities or regions) requiring specific measures (either financial or regulatory), hence the mobilisation of available policy instruments at urban and regional scale.

DG JRC is contributing to the Territorial Impact Assessment (TIA) pilot exercise promoted by DG REGIO for the review of the EPBD with two interconnected activities: a) collection of detailed data (EU28-wide coverage) on building typologies and characteristics; b) the computation of energy-related indicators at fine geographical resolution.

This document describes a methodological approach developed to estimate the energy demand of buildings at the local scale. It also provides and update on datasets compiled as part of the project, as well as provisional results for two regional case-studies in Italy and the Netherlands.

2 Method

The JRC-LUISA modelling platform was selected to carry out the Territorial Impact Assessment (TIA) pilot on the Energy Performance of Buildings Directive.

The LUISA Territorial Modelling Platform has been developed by DG JRC in order to contribute to the evaluation of impacts of policies and socio-economic trends on European cities and regions. In order to accomplish this task, the LUISA platform is based on a wide knowledge base that undergoes a regular process of updates and improvements. Geographically referenced data from diverse sources are integrated in a consistent way, ensuring alignment of data nomenclature, quality and resolution.

Different territories across Europe, such as countries, regions or cities, can be compared, in terms of land functions indicators: social, economic and demographic trends, resource use, availability and access to infrastructures, and environmental performance. The comparison can refer to the current state or to future (projected in time) scenarios.

In particular for the residential sector, LUISA is equipped to downscale and project energy consumption trends, as function of spatially-detailed variables (from building to municipal level): buildings and households characteristics, climatic factors and urban.

The LUISA group developed a methodology (detailed in Figure 1) based on the use of statistical regression techniques to estimate the influence of the above mentioned variables (predictors) on energy consumption in residential buildings at the local level (municipality). It makes use of a combination of top-down disaggregation of information available at the national and regional levels with detailed data collected from cadastral databases (or equivalent national sources). This approach allows the construction of detailed maps of energy consumption levels, and building, dwelling and household characteristics as of now (reference year of their current status is typically between 2012 and 2015) and under expected future projections (2020, 2030 or 2050).

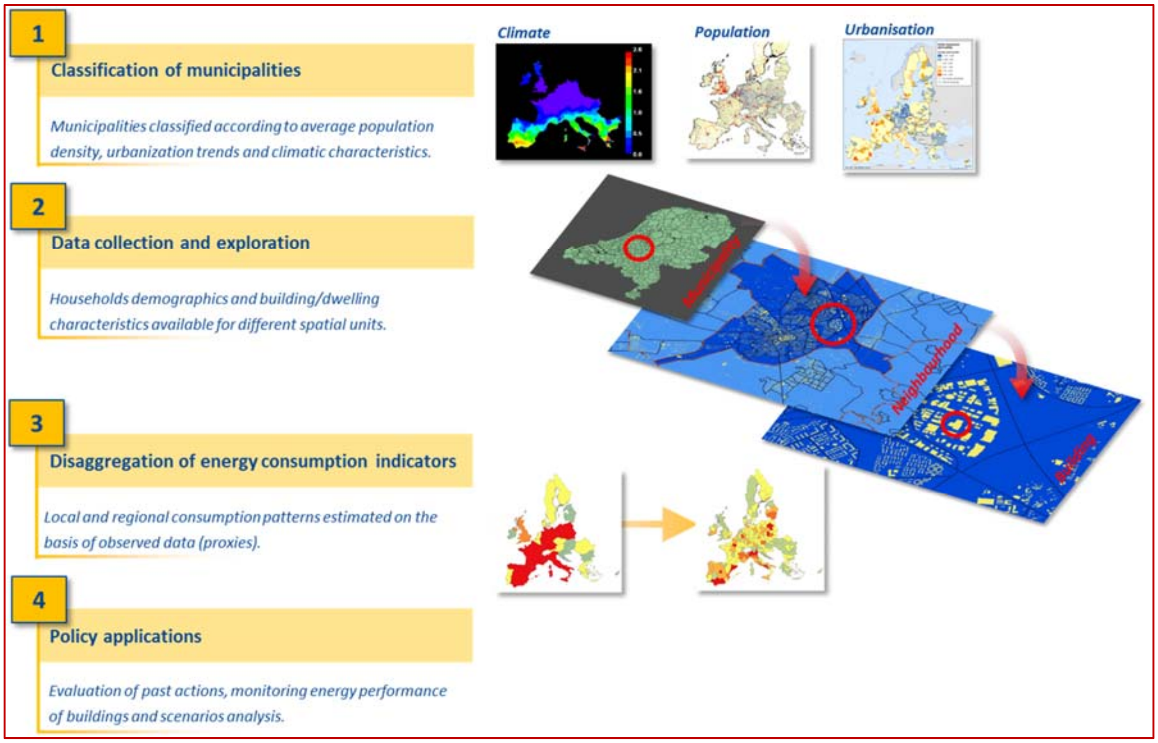

Figure 1. JRC-LUISA Methodology.

The method is composed of four steps:

1. **Classification of municipalities:** Municipalities are classified on the basis of a set of parameters such as population density, urbanisation trends, geographical and climatic characteristics (e.g. altitude, Heating Degree Days, Cooling Degree Days, availability of Solar Radiation etc.).

2. **Data collection and exploration**: Energy consumption in buildings is derived from household demographics (age of oldest person, etc.) and building/dwelling characteristics (period of construction, heating system, etc.) as collected for each country and aggregated at the municipal level.

3. **Disaggregation of energy consumption indicators**: Energy consumption at the municipal level can be estimated using relative weights, which are calibrated for groups of similar municipalities.

4. **Evaluation of indicators in policy applications**: Evaluation of past actions: are there areas where the EPBD was more effective than other areas (e.g. city centre vs suburbs, etc.)? Monitor energy performance of buildings; scenarios: identify priority areas for intervention ("long-term renovation strategy"); evaluation of potential attainment of zero-energy targets.

The territorial dimension of the LUISA platform provides detailed dynamic elements which add particular value to the analysis. For example, population changes (Figure 2) at a fine spatial resolution between the years 2010, 2030 and 2050 (according to the EU Reference Scenario 2013 - Baranzelli et al., 2014) are combined with socio-economic parameters to project the amount of built-up area used per inhabitant (Figure 3), a key indicator to evaluate spatial patterns of urban development and trends. Other available indicators concern urban structure (e.g. green areas, transport networks and recreational spaces) and environmental performances (e.g. sectorial emissions that are directly correlated to energy consumption) and provision of services (e.g. technological and industrial plants, schools, hospitals, etc.).

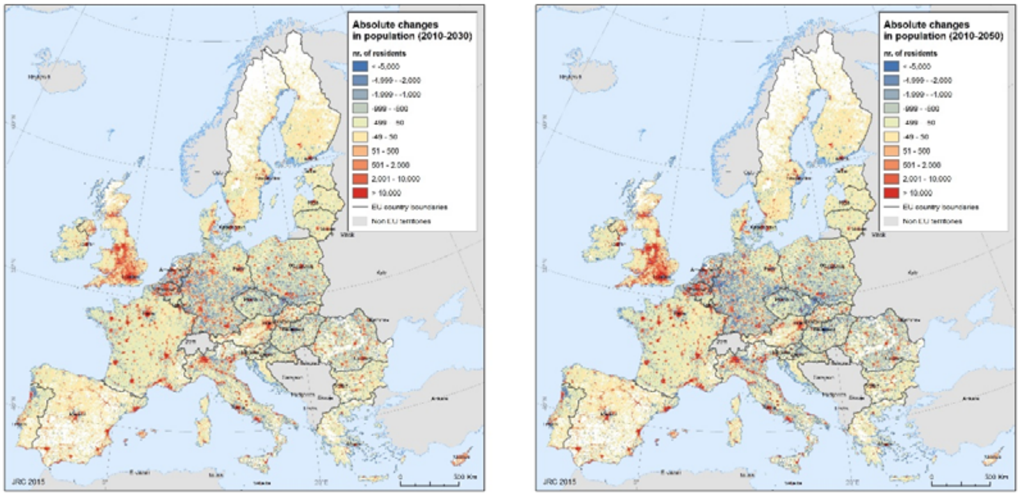

Figure 2. Changes in resident population in the period 2010 – 2030 (left) and 2010 – 2050 (right)

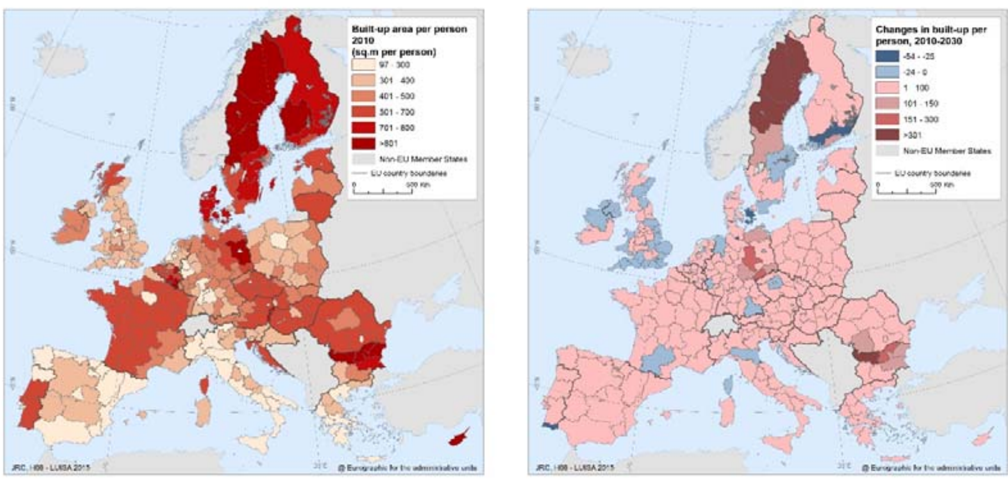

Figure 3. Built-up area per inhabitant 2010 (left), Changes in Built-up area per inhabitant 2010 - 2030 (right)

2.1 Data sets compilation

2.1.1 Data on dwellings

Census population and building characteristics data was downloaded from the national offices of each of the EU-28 countries. The type of information collected by member states varied; with some countries (AT, BG, CY, GR, LT, LU, MT, UK) collecting only basic information on the building date of dwellings (grouped in broad categories) while other collected more detailed information on the types of dwellings e.g. apartment vs houses, their size, occupancy status, their built date, tenure status, number of rooms, household composition, construction material, heating type, and renovation rates.

This data was harmonised to provide, at LAU2 level, comparable information relative the the age of buildings.

From this dataset, two indicators, aggregated at the level of Cities, Functional urban areas, Metro regions and degree of urbanisation, were derived: (1) the proportion of old buildings (Figure 4 to Figure 6) and (2) the proportion of new buildings (Figure 7 to Figure 9). These indicators have been incorporated in the Urban data plaftorm (http://urban.jrc.ec.europa.eu).

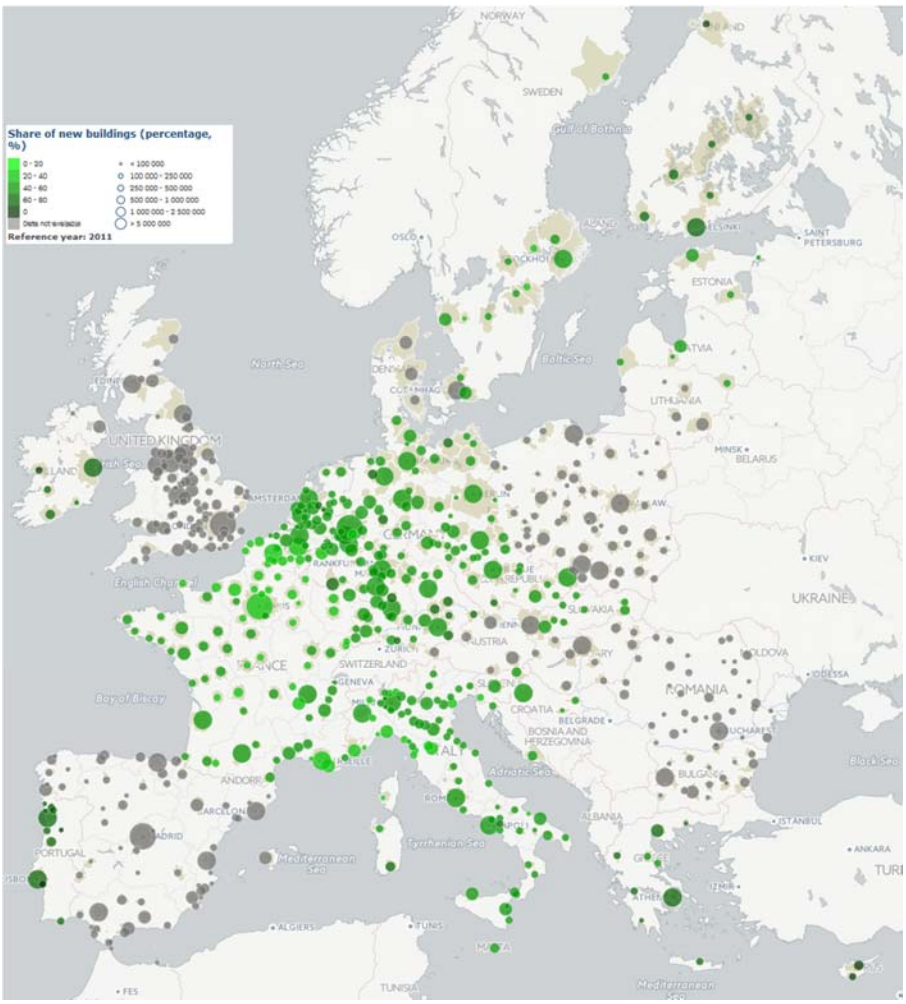

Figure 4: Share of new buildings by Functional Urban Areas

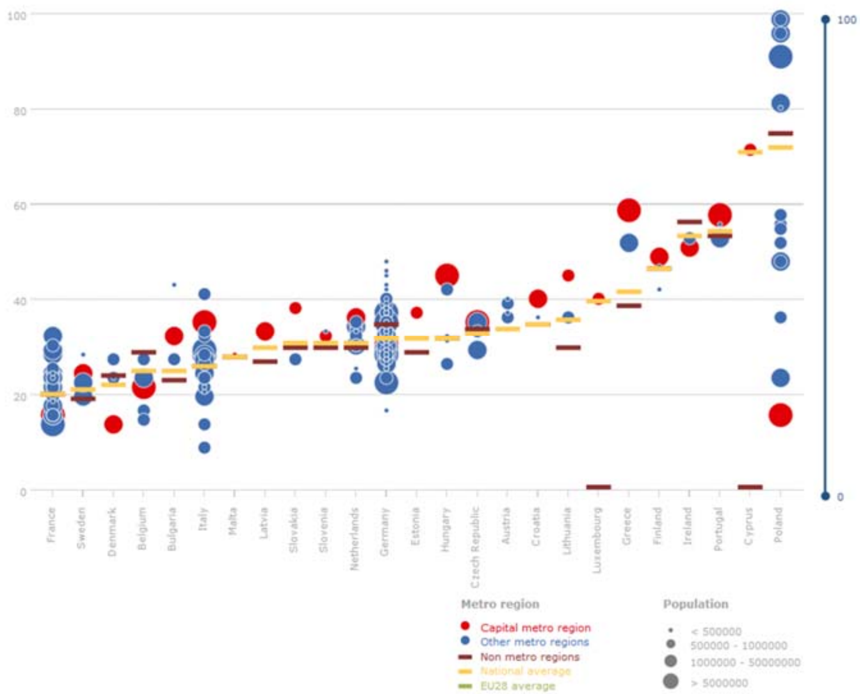

Figure 5: share of new buildings by metro regions

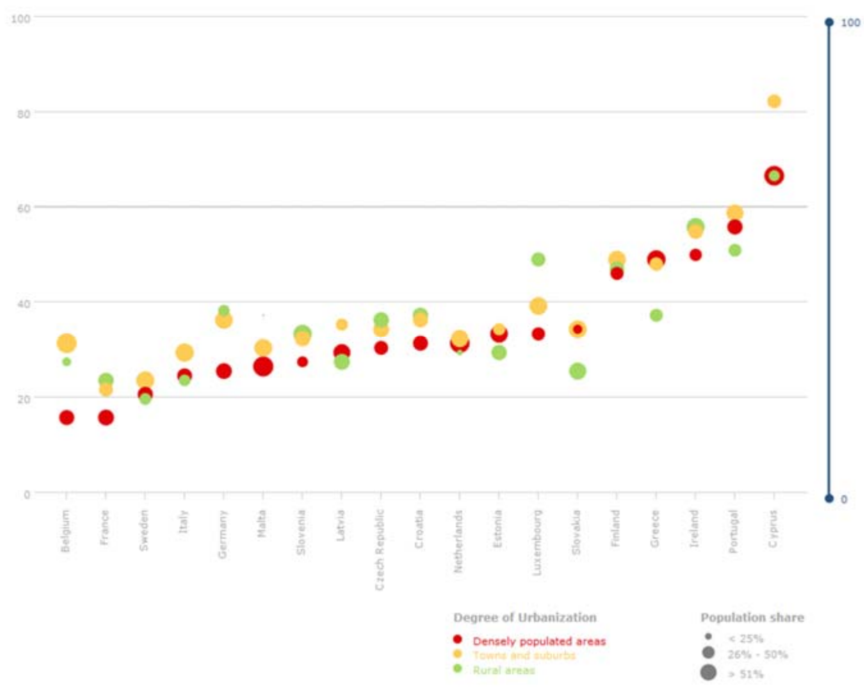

Figure 6: share of new buildings by degree of urbanisation

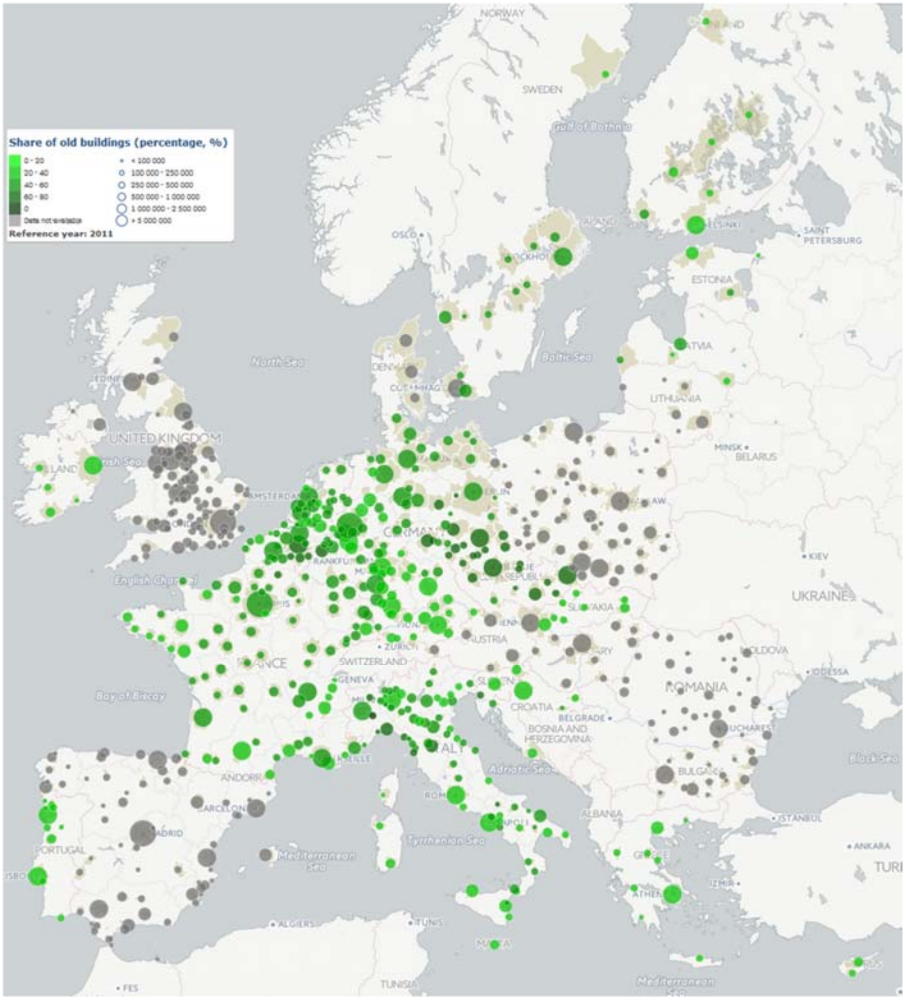

Figure 7: Share of old buildings per Functional Urban Areas

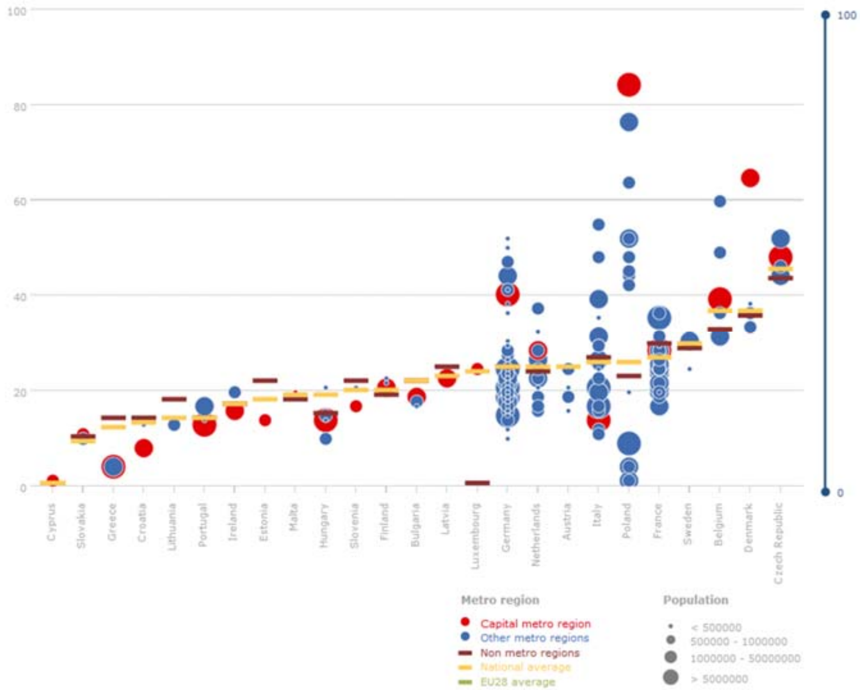

Figure 8: share of old buildings per metro regions

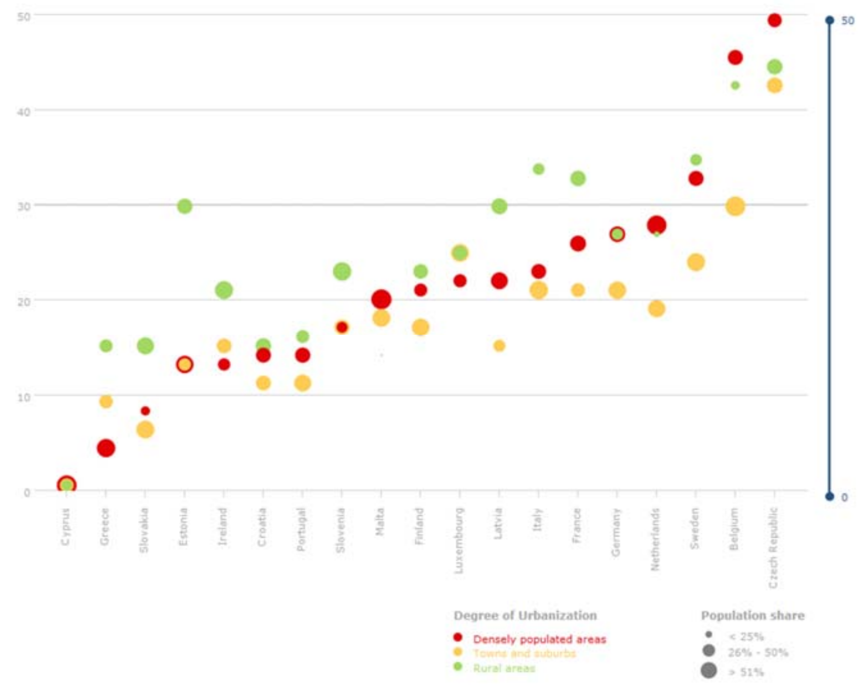

Figure 9: Share of old buildings per degree of urbanisation

Other data, such as municipal data on energy consumption, energy labelling of buildings, micro-scale analysis (data and simulations on representative residential buildings), as well as detailed demographics patterns (current and projected), urbanisation trends, spatial characteristics (density of building, detailed mapping, etc.) was also collected for sample cities.

2.1.2 Climate and weather data

The energy demand of dwellings is strongly affected by the need to keep them warm (in winter) and cool them down (in summer). These needs are themselves strongly correlated with the climate and weather to which the dwelling is exposed.

Historical weather data (including daily mean temperature, daily minimum temperature, daily maximum temperature, daily precipitation sum and daily averaged sea level pressure) was obtained from the European climate Assessment & Dataset (http://www.ecad.eu/download/ensembles/download.php#maps) and processed to produce maps of heating degree days and cooling degree days.

Projected data on temperature (Tmin and Tmax) and solar Radiation (sources: E-OBS, PVGIS, etc.) was also collected and is now being processed in order to compute alternative climate indexes.

3 Case Studies in Italy and the Netherlands – preliminary results

Two case studies were developed to illustrate the added value of using the LUISA method for the TIA: national figures of total gas consumption referred to the current state (year 2012) have been downscaled to municipal level for the Netherlands and the region of Emilia Romagna in Central Italy (Figure 10).

For both cases, the disaggregation procedure is based, at the municipal level, on the total number of used dwellings and estimated relative influence that building and dwelling characteristics have on gas consumption per household. The factors considered were: building age, building material, building type, dwelling area, dwelling value and occupants' age. The selection of these factors was based on data availability and exploration (e.g. identification of outliers, collinearity effects, dependency structures, balanced data requirements, etc.).

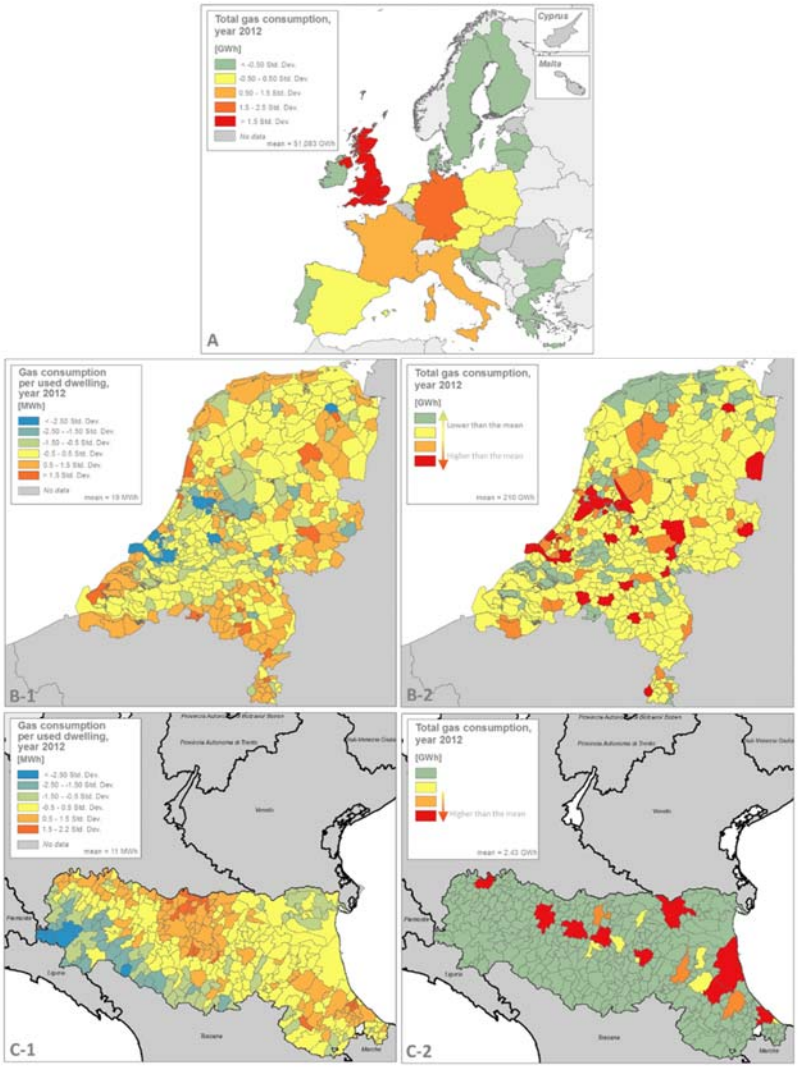

Figure 10. Total gas consumption for the year 2012 at national scale (panel A; source: ODYSSEE), and disaggregation at municipal level for the Netherlands and Emilia Romagna region (panels B-1 and B2, and C-1 and C-2, respectively; source: JRC-B3)

Figure 10 presents the difference in municipal gas consumption (total and per-dwelling) compared to the average national gas consumption for the Netherlands (NL) and the regional average for the region Emilia Romagna (ER). Although not complete and preliminary, the two case studies allow for some considerations:

The ER presents a more homogeneous distribution of gas consumption, with peaks in urban agglomeration or in specific rural locations, suggesting to focus the analysis on these areas to identify causes and potential local actions.

The NL presents a more scattered distribution, driven by the geo-morphological characteristics of the urbanisation patterns. Measures could therefore be taken at more general level, with specific action on the agglomeration with high consumptions.

These two case studies are provisional. Due to timing constraints, the estimated statistical models have been only partially validated. The final specification of the models shall be delivered after a thorough validation procedure has been carried out. Furthermore, due to data and timing constraints, climatic factors have not been yet included in the two case studies hereby presented. In particular, climate factors that should and are going to be included in the analysis are: heating and cooling degree days, solar radiation and other local variables that are likely to exert a not negligible influence on energy consumption levels in residential buildings. Among these additional factors, it is worth mentioning the presence of green spaces in urban areas (see Figure 11 as example).

This disaggregation exercise could be performed with total gas consumption, and also with other energy consumption variables such as total energy consumption or energy consumption due to heating. Furthermore, some of the data that have been used for the two case studies hereby presented, were originally available at neighbourhood (sub-municipal) level. Last, the proposed methodology, based on the use of detailed data, can also be potentially applied to other sectors (e.g. commercial buildings, offices, etc.).

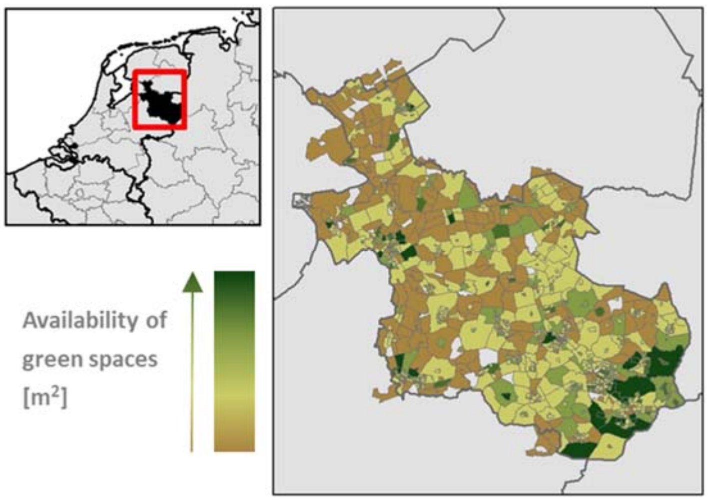

Figure 11. Availability of green spaces (not classified as urban forest), expressed in m2. The indicator is represented at neighbourhood level for the Overijssel region in the Netherlands. Source: JRC-B3 elaboration based on the Global Human Settlement Layer (global layer developed by JRC-G2)

4 Next steps and potential scenario investigations

Making use of the data collected and the experience learnt in the development of the two above case studies, a range of potential applications will be considered.

These may include:

- An expanded downscaling of the energy consumption of buildings across Europe (depending on the availability of data) and identification of spatial patterns, at the municipal level or within single cities, of energy consumption;
- An estimation of the potential impacts of policy measure to improve building isolation and reach the "nearly zero energy' target as well as identify priority areas for intervention;
- An estimation of the potential impact of climate change and / or population changes on residential energy demand in Europe;
- The identification of potential synergies with other thematic policies such as regional development policy.

References

Baranzelli, C., Jacobs-Crisioni, C., Batista, F., Perpiña Castillo, C., Barbosa, A., Torres, J. A., Lavalle, C. ,2014. The Reference scenario in the LUISA platform – Updated configuration 2014 Towards a Common Baseline Scenario for EC Impact Assessment procedures.

List of abbreviations and definitions

EPDB: Energy Performance Building Directive

EREBILAND: European Regional Energy Balance and Innovation Landscape

EU: European Union

LUISA: Land Use-based Integrated Sustainability Assessment modelling platform

TIA: Territorial Impact Assessment

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LF-06-16-344-EN-N

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doi:10.2791/462472
ISBN 978-92-79-64400-9