A method for categorization of European historic districts and a multiscale data model for the assessment of energy interventions

T. Brostrom[1], A. Bernardi[2], A.r Egusquiza[3], J. Frick[4], M. Kahn[5]

ABSTRACT

The European project Energy Efficiency for EU Historic Districts Sustainability (EFFESUS) aims to develop and demonstrate a methodology for assessing and selecting energy efficiency interventions in historic urban districts. This paper will give an overview of the whole project with a focus on the methodology and results from the first part of the project including the following steps: Identification and collection of existing data on historic urban districts, establishment of impact indicators for energy retrofit measures, identification and evaluation of European and national policies and legislation, development of a categorization method, and development of a multi scale data model

Keywords

Energy efficiency, historic districts, categorization, data model, EFFESUS

1. Introduction

Historic buildings constitute around one quarter of the European building stock. They are an important part of our built heritage even though most of them are not formally protected. In Europe, historic urban buildings consume 4% of all energy and are responsible for 3% of CO2 emissions. Therefore, improving energy efficiency in historic buildings and historic districts is essential.

The European project Energy Efficiency for EU Historic Districts Sustainability (EFFESUS) aims to develop and demonstrate a methodology for assessing and selecting energy efficiency interventions in historic urban districts. This paper will give an overview of the whole project with a focus on the methodology and intended results from the first part of the project where the aim is to develop a structured categorization and multi scale data model for the European stock of historic urban buildings.

2. The EFFESUS project

The EFFESUS project is funded by the European Commission, running from 2012 to 2016 and involving 23 partners from 13 European countries. EFFESUS aims to investigate energy efficiency and sustainability of European historic urban districts and measures and tools to make significant improvements whilst protecting their heritage value. The project will develop new technologies; provide training and awareness activities; and demonstrate its results in real case studies in seven historic urban districts: Bamberg (Germany), Budapest (Hungary), Genoa (Italy, Glasgow (United Kingdom), Istanbul (Turkey), Visby (Sweden) and Santiago de Compostela (Spain).

The main deliverable of the project will be a decision support system (DSS), an expert system that provides users with support in the identification and prioritization of interventions for improving energy efficiency in historic districts. The methodology and the DSS will focus on the initial stage of the retrofitting process at district level, in which the retrofitting framework is established. The objective is to facilitate informed decisions on the selection of strategies and technological solutions.

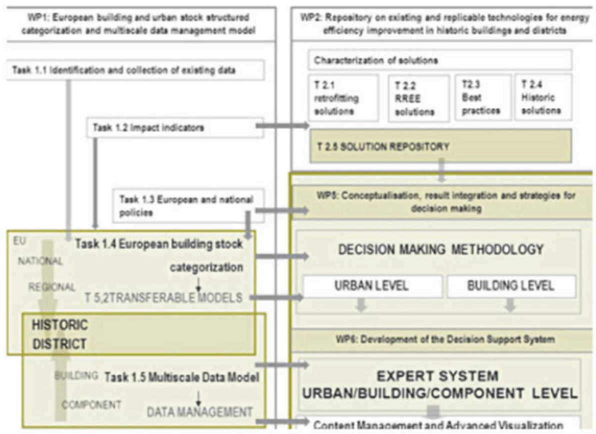

Figure 1: The flow of information in the EFFESUS project

Decision making will be based on the data both of the historic district and of the retrofitting solutions. This paper will focus on the first phase of the EFFESUS project, which is divided into five tasks:

1. Identification and collection of existing data (Completed in June 2013)
2. Establishment of impact indicators (Completed in June 2013)
3. Identification and evaluation of European and national policies and legislation related to energy efficiency and cultural heritage conservation (Completed in June 2013)

1 Uppsala University, Sweden;
2 CNR-ISAC, Italy;
3 Tecnalia, Spain;
4 University of Stuttgart, Germany;
5 Norwegian University of Science and Technology

4. Development of a structured organization and categorization method (Completed in September 2013)
5. Development of a multiscale data model (Completed in November 2013)

Task 1, 2 and 3 will provide input for tasks 4 and 5 as shown in fig 1. In the following, each task will be presented more in depth.

3. European building and urban stock data

The objective of this task was to identify existing data in relation to the requirements for the structured categorization (Task 1.4) and for the data management model (Task 1.5). The data about historic districts will be dealt with on three levels of detail:

1. European historic district typologies in general
2. Specific historic districts
3. Multiscale data model for detailed information about a historic district.

Since there are many sources of data of varying content and quality, criteria for the data collection have been established in order to identify the most suitable databases. These criteria are:

- Quality, update status, and type of information
- Scale and geo-references
- Domain and thematic areas, and language Format and accessibility

Based on the above mentioned criteria, existing data in Europe with focus on the countries of the EFFESUS partners have been identified and evaluated. This includes a statistical presentation of the age distribution in the European building stock and of the literature on energy consumption and energy refurbishments in historic buildings. In addition, data on building typology and on availability of georeferenced data were identified. The latter covers the following categories: geometry (districts, buildings: location, terrain, level of detail, space, volume, etc.), climate (climatic regions, microclimate, etc.), building (construction typology and materials, building age and usage, protection, retrofitting state, etc.), and energy (provision, sources, heating/cooling systems, consumption, etc.). The data sources were described, evaluated and listed in the task report [3] which will be provided on the homepage of the EFFESUS project. The major findings are as follows.

3.1 Historic stock

The survey shows that the historic building stock in Europe (EU 28, Norway, Switzerland, and Turkey) accounts for around 23.1 % of all buildings. The national age classes vary, therefore the border range between historic and non-historic buildings is in the interval 1945 to 1950. In general the protected stock is only a small part of the historic stock, even though some conservation areas are taken into account. Thus data of the heritage authorities cover only a smaller part of the historic building stock, which implies that for the majority of historic buildings there is no information about the cultural value or building structure in public data bases.

3.2 Building and georeferenced data

The access to and quality of national building data varies greatly and will be a limiting factor. For the case studies, additional data will be actively collected. Most countries provide georeferenced 2D or 3D information on buildings. In general up to Level of Detail 2 data (3D with roof forms) are available for most of the case studies (see Figure 2). Data with higher levels of detail are not generally available. They must be collected separately for any chosen district.

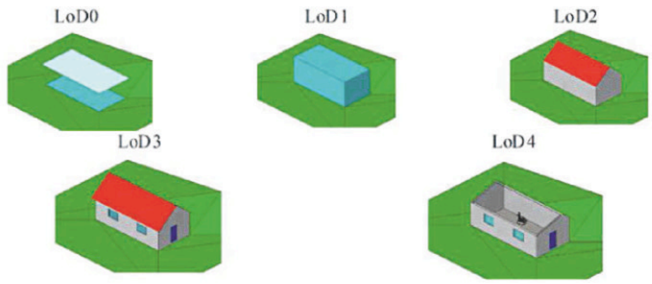

Figure 2 Different Levels of Detail (LoD) to represent a single building.

3.3 Climate data

The survey of available data showed that there is not sufficient data on climate. To overcome this problem EFFESUS will use climate data from the European project Climate for Culture [1]. This project will provide outdoor climate data for the periods of 1960 – 1990, 2020 – 2050 and 2070 – 2100 with a resolution of 10 km to 10 km grid size for Europe and the Mediterranean [2]. The first period will be validated by real measured data.

3.4 Energy data

Data from the various national energy certification schemes can be useful. However, the heterogeneous structure and content makes it difficult to define a common method. In some countries data are linked to an address, in others it is anonymous. The assessment of energy performance must be based on actual energy consumption for several years, corrected by the actual climate of the period [4]. Data based on calculated values are not reliable, because of incorrect representation of constructions and materials of historic buildings. [5]). An example from Germany shows, that the refurbishment of buildings before 1919 can be less effective compared to buildings in the period 1919 to 1948, because they have more architectural features on facades and details which result in more complex tasks for retrofitting [4,5]), see fig 3. It may be of interest to perform such analyses for different European countries or regions.

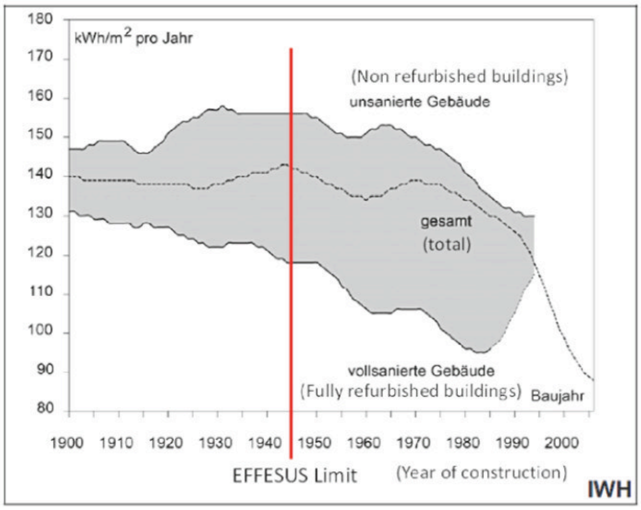

Figure 3 Comparison of heating energy use depending on the year of construction of domestic multi-family buildings in Germany. The upper curve indicates use of non-refurbished buildings; the lower curve of fully refurbished buildings; and the middle curve represents the whole analysed stock. [5]

4. Impact indicators

Energy efficiency measures in historical buildings and districts require particular attention since the conservation requirements and purposes need to be respected and guaranteed, in addition to the objectives of economic return and sustainability. For this reason the suitability of a retrofit measure and its impact should be assessed considering the following categories: indoor environmental conditions, building and urban fabric compatibility, historical values and conservation principles, embodied energy, operational energy and economic return.

4.1 Overall methodology

To facilitate a systematic assessment of the above mentioned categories, a number of impact indicators have been identified. Indicators are defined in the UNI norm 11097:2003 as "qualitative and / or quantitative information associated to a phenomenon (or a process or a result) under observation, which allows you to investigate the changes over time, as well as to verify the accomplishment of a goal, in order to allow for proper decision-making" [9]. A similar definition was found also in the European project PERFECTION. Here, indicators are defined as "quantitative or qualitative measures which can be compared to specific standards, thresholds, guided values or principles, in order to assess the performance of products, building components, buildings in relation to an objective" [7].

Impact indicators specific to this project were developed following this approach, see fig 4:

- For each category a list of impact indicators was defined in the form of subcategories or science areas;
- Each impact indicator was in turn divided into specific indicators, for which the related standard or guidelines were specified and also the exiting target or recommend values.

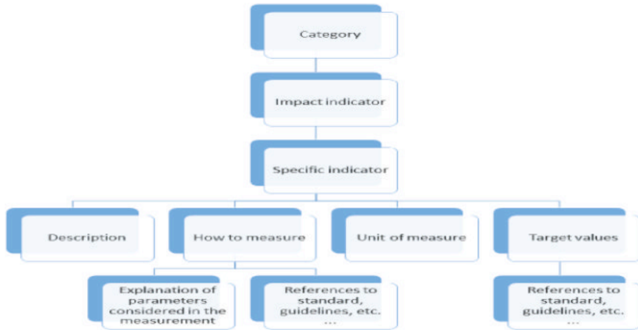

Figure 4: The approach for defining impact indicators

Subsequently, a short list of impact indicators has been identified from the wide array of topics found in the literature. The choice of the most relevant indicators for the EFFESUS project, in particular for the development of the decision support system (DSS) tool, was accomplished on the basis of the interaction with other work packages. The result is a first broad selection, which will be refined throughout the project's development according to the results of the following the EFFESUS work packages and in function of its usefulness for the DSS tool. The development is still in progress and the final selection of impact indicators will be made in close cooperation with the development the DSS tool.

4.2 Results and recommendations

A common approach to the use of the indicators was defined, in order to connect the quantitative assessment of the technical or practical categories with the qualitative assessment related to historical values and conservation principles. Hence, for each category or subcategory a five point scale was established for the evaluation of the impact indicators both in the initial conditions and after the implementation of the possible retrofit measures. The first assessment of the existing stock can be based either on existing data sources or on field assessment, while the impact of the interventions may be derived from the repository of existing technologies and systems for energetic retrofitting. The required qualitative assessment values should be established by qualified professionals with experience in dealing with historic buildings (e.g. specialist conservation architects, specialist conservation-experienced structural engineers, building physicists with specialist experience in assessing historic building fabric). Assessments should be carried out using state-of-the-art expertise and will need to precisely describe the knowledge gaps relevant to the assessment carried out.

The proposed method is to weigh the above outlined assessment categories against each other, in order to evaluate the impact and the related risk of the implementation of a particular retrofit measure on a particular building or urban fabric. The results of the assessment of the existing stock and later of the impact / risk of the possible retrofit measures, might not be in the form of absolute values, but rather in the form of probability and risk assessments:

- retrofit measure likely to be suitable;
- retrofit measure might be suitable;
- retrofit measure suitable;

- · retrofit measure likely not to be suitable.

The aim is to obtain an overall assessment of the suitability of the intervention in question and for the specific case in function. This can help to prioritize retrofit measures and indicate the degree to which further specialist assessment will be required.

The recommendation for the DSS system is that it should be iterative with the first iteration using this relative scale of indicators to determine the initial relative suitability of various retrofit measures. When this is achieved, the resulting smaller list of suitable retrofit options can be investigated in detail for the specific building, district and location using external tools recommended by the DSS. The detailed results obtained can then be fed back into the DSS tool for a second iteration and selection of the most suitable options.

Even though some recommendations on how to use the impact indicators were suggested, their integration within the DSS tool and the overall method will be further developed in the course of the EFFESUS project.

5. Identification and evaluation of European and national policies and legislation related to energy efficiency and cultural heritage conservation

In order to assess the potential for energy interventions in a historic district, the legal framework must be defined. The objective of this task was to make an overview of the current European and national legislation including international charters and EU directives in order to define the relationship between legislation and policies for heritage protection on one hand and energy efficiency on the other.

In a first stage, the method and scope of a European survey was defined. A questionnaire was distributed to all partners. In parallel, information on EU law (EPBD) and international conventions and charters were collected. Data collected from the questionnaire was systematized and analyzed. The following is a summary of the findings.

The results show no direct conflict between legal systems, neither on international, European nor national level. One reason for this may be that European legislations and the international legislations have broad formulations. This is especially true of international conventions and charters, which are considered "soft law", this refers to quasi-legal instruments which do not have any legal binding force and serve mainly as guidance. Regulatory authorities in each country are therefore relatively free to adapt the requirements to national regulations in a way ensuring that they do not come into conflict with existing national legislation. Unclear or undefined legislation leads to considerable room for discretion, which in turn leads to different practices, based on political composition. Lack of legal conflicts is probably also related to the fact that most participating countries seems to have adopted the Directive EPBD 2010 fully. This also applies for the participating countries which are not a member states.

EU law makes a clear distinction between officially protected buildings or environments and non-officially protected buildings or environments, where non-officially protected buildings or environments in principle shall be treated equally with all other existing buildings and environments, when it comes to requirements for energy efficiency. This concept is implemented in the guidance document "Cost-optimal methodology framework".

The survey also shows that communication and cooperation between relevant bodies can be improved. A close dialogue between relevant public bodies should lead to the development of a common national standard. There is further a need to develop a common method of cost-optimal methodology framework which is suitable for historic buildings and environments. Existing methods are not designed to deal with the specific problems which occur when the requirements are applied to historic buildings. A method that is particularly suitable for historic buildings, will not only be useful for calculating efficiency without harming the building or environment, it is likely that it leads to the current policy and practice to follow.

6. Development of a structured organization and categorization method

For practical reasons, the investigation of the potential for energy improvements in a historic district as a whole cannot be made on a house by house basis. The building stock must somehow be reduced to a manageable number of categories that provides a satisfactory statistical representation of the whole stock. Thus a limited number of typical sample buildings would represent the whole building stock in question. In addition to this, the district can be represented at a communal level with information on energy supply, possibilities for local energy production etc.

This approach has been used to assess the potential for energy improvements in general. A study to investigate the potential and cost for reducing the environmental impacts of residential buildings in the European Union, [6] used national statistical data to categorize the building stock in the EU. Based on geographic location, age, design and technical characteristics, 72 categories were selected. These categories were estimated to represent around 80% of the building stock in the EU. The European project TABULA [8] has presented national building typologies representing the residential building stock of their countries in order to assess the potential for energy savings. In a Swedish study by the National Board of Housing, 1800 buildings were statistically chosen to represent the entire building stock.

Even though the previous projects use a variety of typologies and categorization schemes, they still define a common platform in terms of methodology and input data specifications.

Based on the previous studies, one can identify a minimum requirement of data that is needed for building categorization on a wider scale.

- Climate zone
- Type of building
- Type of use
- Size
- Age of construction
- Building envelope
- Heating/cooling system

Existing typologies and categorization methods are useful in the EFFESUS context, however in the context of the EFFESUS project they have to be developed further to take into account the impact factors that are specific for historic districts. As the access to and quality of national building data varies, the method of categorization has to be flexible. The EFFESUS categorization is being developed and will be tested and verified using the world heritage town Visby as a case study.

Figure 5 The district will be represented by a number of typical buildings.

7. Development of a multiscale data model

To achieve the project objectives, a proper strategy for the management of data is needed. In order to enable an informed decision, this strategy should link the information at different scales (city, district, building and component) and from different domains (infrastructure, housing, mobility, energy etc) Therefore, it will be necessary to design a data model that allows the domain knowledge to be organized within a complete and unique model, which will feed the DSS.

After the identification of the general requirements of the model and the analysis of the existing representation standards, it has been decided to develop the model based on CityGML, which is a standard data model for the representation of 3D city models that combines semantic and geometric information. This is an application of the Geography Markup Language (GML3) that enables the exchange of spatial data. Both are standards approved by the Open Geospatial Consortium (OGC). The requirements that are fulfilled by a data model based on CityGML are the following:

- It should include semantic and geometric information properly related and georeferenced. CityGML not only represents the geometry, topology and appearance of objects in a consistent and homogeneous way. It also represents semantic and thematic properties, taxonomies and aggregations.
- It should interconnect the information at different scales and levels of detail. CityGML can represent graphical data at different Levels of Detail (LoD) see fig 1, reusing semantic information. Different LoD allow visualization and analysis of data at different resolution and scale, depending on the requirements of each application. In this way the strategic scale (urban) and the operative scale (building-component) are connected within the same model. Moreover, thanks to its interoperability, it is possible to connect the city scope with more detailed building or component models such as BIM models (Building Information Modelling) and with territorial level systems (GIS - Geographic Information System).
- It should be interoperable with the other outputs of the EFFESUS project, but also with other existing data models and external tools for management analysis and decision making. As City GML is an international standard, the model will be interoperable with other data models and tools (analysis, management, decision-making ...)
- The model should be domain-independent but should be extensible in order to incorporate domain-specific information for energy assessment and management. CityGML is intended to be a universal model independent of the application domain, but it allows users to create new entities or to characterize existing ones with new attributes, according to their needs,. To simplify this process and to increase its flexibility, CityGML defines the Application Domain Extension (ADE). Once formally specified, documents can be validated according to it; while compatibility is maintained with the original tools based on CityGML.

The data model will be fully implemented in the case study of Santiago de Compostela.

8. Conclusion

This paper has shown the progress of the EFFESUS project towards a method for categorization of European historic districts and a multi scale data model for the assessment of energy interventions in historic urban districts. In relation to the information needed in the project as a whole, available data sources have been identified. A general methodology for the assessment of measures has been developed and impact indicators have been identified. In a survey, European and national policies and legislation related to energy efficiency and cultural heritage conservation have been identified and evaluated. The development of a structured organization and categorization method has been initiated and a new method will be tested and validated using one of the case studies. Finally, the requirements for a multi scale data model have been defined and a data model based on CityGML will be developed implemented in the case studies.

9. Acknowledgements

The present study has been supported by the European Commission under the project of the 7th Framework Program Energy Efficiency for EU Historic Districts Sustainability (EFFESUS), No. 314678.

In addition to the authors, the following persons have contributed to the paper:

Arianna Vivarelli, Francesca Becherini CNR-ISAC

Manuela Reichert, University of Stuttgart

Anna Donarelli and Petra Eriksson Uppsala University

Jose Luis Izkara and Iñaki Prieto, Tecnalia

10. References

[1] Climate for Culture: homepage of the project: http://www.climateforculture.eu/index.php?inhalt=home [accessed June 2013]

[2] Erhardt, D.; Antretter, F. (2012): Applicability of regional model climate data for hygrothermal building simulation and climate change impact on the indoor environment of a generic church in Europe. In Proceedings of the 2nd European Workshop on Cultural Heritage Preservation EWCHP-2012, Kjeller, Norway 23rd to 26th September 2012. ISBN: 978-82-425-2525-3, 99-105.

[3] Frick, J.; Reichert, M.; Panzehir, M.; Egusquiza Ortega, A., Prieto Furundarena, I.; Broström, T., Donarelli, A.; Fernández Arias; A.; Ragna Grytli, E.; Troi, A., Exner, D.; Stuart, J.; Papavasiliou, G.; Tsoutis, C.; Hermann, C.; Changeworks, Heriot-Watt University; Rodwell, D.; Ochoa, M; Dimitrijevic, T.; Hrabovszky-Horváth, S.; Zsidek, G.; Schindler, C.; Wachtmann, B.; von Rettberg, B.; Gouas, V.; Gouas, F.; Cakir, P. (2013): Deliverable D1.1: European building and urban stock data collection.

[4] Michelsen, C. (2010): Im Fokus: Der lange Weg zur Energieeffizienz von Immobilien – Ergebnisse des ista-IWH-Energieeffizienzindex. Wirtschaft im Wandel, vol. 3, 2010, 136-141. http://www.iwh-halle.de/d/publik/wiwa/3-10-3.pdf [accessed June 2013]

[5] Michelsen, C.; Müller-Michelsen, S. (2012): Energieeffizienz im Altbau: Werden die Sanierungspotenziale überschätzt? Ergebnisse auf Grundlage des ista-IWH-Energieeffizienzindex. Wirtschaft im Wandel, vol. 9, 2010, 447-455]

[6] Nemry et al. 2010. Options to reduce the environmental impacts of residential buildings in the European Union—Potential and costs. Energy and Buildings 42 (2010) 976–984

[7] Steskens P., Loomans M., 31 January 2010. T1.3 Performance Indicators for Health and Comfort. Deliverable of FP7 project PERFECTION (Grant Number 212998).

[8] Tabula. 2012. Typology approach for building stock energy assessment. http://www.building-typology.eu/

[9] UNI 11097:2003. Gestione per la qualità - Indicatori e quadri di gestione della qualità - Linee guida generali.