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ScienceDirect
Energy Procedia 78 (2015) 1853 – 1858
Energy Procedia

6th International Building Physics Conference, IBPC 2015

Interconnection between scales for friendly and affordable sustainable urban districts retrofitting

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Abstract

The EU FP7 project FASUDIR (Friendly and Affordable Sustainable Urban Districts Retrofitting) supports the mobilization of the building retrofitting market towards 2020-2050 EU-targets through an Integrated Decision Support Tool (IDST), a software based on a new methodology that will help decision makers identify the best energy retrofitting strategy to increase the sustainability of the whole district. Improving the sustainability of urban environments is a interscalar problem, addressed through a multiscalar and multidirectional approach. A comprehensive urban scale strategy considers the working scale, but the measures at building scale have to be coherent with the global objectives at district and city scale. The FASUDIR IDST and methodology interconnect and visualize information across scales, ensuring comprehensive diagnoses and proper implementation of strategies. Due to the complexity of urban sustainability, interscalarity and multiscalarity, first it has been necessary to identify the possible scales of analysis, to capture various themes and to highlight the horizontal and vertical interconnections between different components. Multiscalarity and Interscalarity affect the three phases of the sustainable retrofitting cycle: diagnosis, decision making and management. The identification of the impact of district solutions on buildings (and vice versa) and their compatibility across scales has been addressed through interconnected building and district Key Performance Iindicators (KPIs). The intervention phases at building level generate new information about specific buildings, enabling more accurate decision making at district level. The methodology articulates the structure of the new information and the feedback generated during the process. To allow information interconnection a strategic information management is key. A multiscale information model based on CityGML, a standard data model issued by the OGC (Open Geospatial Consortium), will be the baseline structure for all the district-scale information (geometric and semantic) that is necessary for decision making and management, organized into a single interoperable data model that will integrate information from different fields and at different levels of detail.
The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 609222.

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL

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Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
doi:10.1016/j.egypro.2015.11.332

SRL. *Keywords:* sustainable; multiscalar; urban; district; retrofitting

1. Introduction

The international debate regarding the interaction between climate change, land-use and energy is focused on the identification of the suitable scale or scales for effective energy planning and a growing number of papers have been dealing with the problem of suitable spatial and temporal scale in the context of energy planning during the last 10 years [1]. Cash and Moser [2] among others argued that global environmental changes are cross-scale phenomena, requiring multi-scale assessments for more effective political and decision-making processes. Kates and Wilbanks [3] noted that, although climate change is truly a global phenomenon, most of the specific adaptation actions can, and must, operate at different temporal and spatial scales, from local to global, and from local energy production policies to international agreements for generating improved outcomes at a global level. There is a wide and growing recognition of the importance of the local scale (e.g. municipal) and cross-scale dynamics (i.e. nested) to address and understand energy and environmental issues [1]. In particular, the study of the built environment ideally requires both fine scale (buildings and streets) and large scale analysis (city-wide processes) [4].

A comprehensive strategy for the sustainable improvement at urban scale has to take into account the executive scale (i.e. the building scale) in strategic decisions. Analogously, the measures to be implemented at building scale have to be coherent with the global objectives at district and city scale.

Therefore the improvement of the sustainability of urban building environments is an interscalar problem that has to be addressed through a multiscalar and multidirectional approach, going from the neighborhood down to the building and up to the city. Multiscalar tools, methodologies and information models are needed to:

- Interconnect information at different scales; city, neighborhood, building block, building and elements;
- Integrate information at fine-scales to make calculations for large urban areas;
- Visualize data at multiple scales;
- Connect the strategic scale (urban) and the executive scale (building/component) to ensure a more integral diagnosis and the proper implementation of the strategies;
- Connect different scale models and standards as CityGML and GIS (Geographic Information Systems).

Such tools, methodologies and information models are the focus of EU FP7 project FASUDIR (Friendly and Affordable Sustainable Urban Districts Retrofitting), aimed at supporting the key stakeholders of urban planning in decision making and implementation. Research in the project has focused on the identification of the various scales of the urban environment, on the definition of the stages of the urban retrofitting process and the multiscalar approach at each stage, on the leveraging of synergies, and finally on the information flow.

2. Scales of the urban environment

Due to the complexity of studying urban sustainability, the first step has been the identification of the different scales of analysis [5], in such a way that the various themes can be captured correctly in their own specific nature and as part of a cohesive whole. In order to introduce the principles of interscalarity and multiscalarity we provide a broad overview of the possible themes in the urban environment and their correlation across scales.

The figure below highlights how some themes are transversal to all scales, while others can only be captured meaningfully in a specific dimensional subset. E.g. energy consumption is relevant and can be analyzed at all scales (with different levels of precision), and used to compare horizontally elements at the same scale; on the other hand, the outdoor levels of comfort cannot be usefully analyzed at the larger city level, as the detailed performance of the various areas get lost in the average territorial performance. Conversely, networks can be studied through a significant sample of their extension, which does not allow for their analysis at smaller scales such as blocks and buildings. The theme does not disappear, however: it is just studied from a different perspective, such as that of the access and connection to the available networks. In the following sections the above scales will be defined through consideration of dimension and perception, highlighting the key elements for each scale.

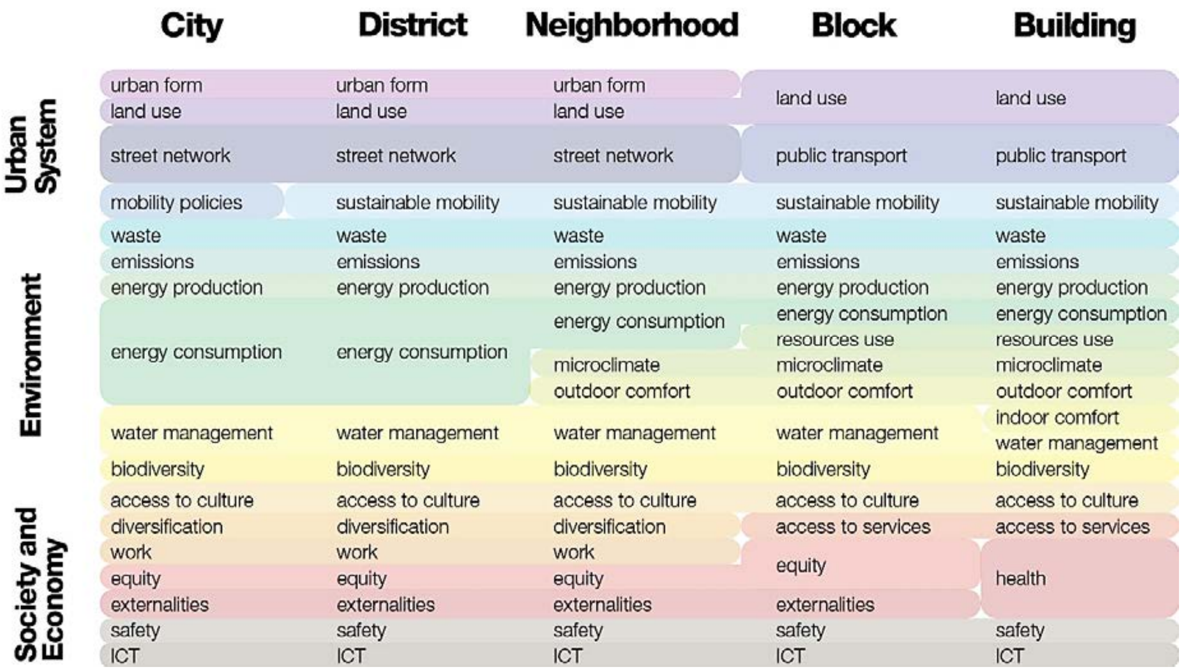

Fig. 1. Sustainability themes at urban scale.

2.1. City scale

This is the largest scale from a dimensional point of view. Its limits are often under discussion, as the city borders are usually defined on a country basis through arbitrary and historic methods, and the overall size is highly variable. At city scale, it is possible to compare performances among cities with respect to energy consumption, resource usage, and waste production. Furthermore, cities as social and economic entities are analyzed on a variety of metrics, to gauge and compare the quality of life. The six topics identified by Giffinger et al. for Smart Cities are Economy, Mobility, Governance, Environment, Living and People. [6]

This scale is most appropriate for a full view of the networks, be they technical (e.g. energy) or logistic (e.g. transportation). The network's connectivity, the distribution of sizes of streets, and the public transport networks are all aspects that can be best studied at this scale or at the district scale: it is necessary to analyze their characteristics at a wide scale, in order to gain a complete understanding of their fit in the whole urban system. The city scale is also crucial to plan correctly the distribution of services with a wide reach. A detailed awareness of the distribution of services is very important in urban policy, and while it starts at city scale, it is detailed at district scale. [5]

2.2. District scale

A district is generally a large subset of a city, with boundaries defined formally through historic criteria of urban development. Usually a district is surrounded by large infrastructure, such as the main transportation lines, which provide a large scale structure to the city; furthermore, a district is usually created (and can be recognized) through a decades-long development and expansion of the city, visible in the period-specific types, technology and function of the buildings, and has a local government. [7] Also, it is important to underline that the variability in size of a city can mean that, in the smaller ones, the district scale overlaps with the entire area of the city. Conversely, by this approach, it is possible to consider districts to be, in some way, smaller cities inside one larger agglomerate.

At the district scale it is possible to evaluate the structure, the complexity, and the connectivity of the street networks, including pedestrian and public transportation. Districts can also be studied under the socio-economic lens, by assessing on a somewhat homogeneous base the social mix, the distribution of functions and activities, the availability of jobs, and the diversity of available housing. They key aspect that is visible at district scale is the functioning of large scale networks of services.

2.3. Neighborhood scale

The neighborhood scale is perhaps the most traditionally recognized: while often it is not defined formally through official city boundaries, a neighborhood is identified as such by its inhabitants as a homogeneous whole, with its specific characteristics and defining traits, be they social, cultural, or architectural.

At the neighborhood scale some elements lose definition, such as the large scale networks, which are now visible only through some of their constituting elements; but others take front stage, especially when considering the inhabitants' daily life. Such neighborhoods elements are the pedestrian and cycling networks, the morphology of the buildings, the microclimate, and the presence of a variety of services.

Specifically, the shape and relation of buildings and streets can be studied at neighborhood scale, to identify the local wind conditions, the solar energy potential, and the sky factor; furthermore, it is the ideal scale to analyze the impact of buildings on each other, to identify critical issues and possible synergies. The user experience is also visible optimally at neighborhood level, where segregation may emerge through further detail on the broad analysis of a district; equity, well-being, and cultural parameters are very relevant at this scale. Identifying the size of a neighborhood can be difficult, especially due to its emergence as a social construct. Some dimensional limits can be of size, such as a square with a size ranging from 200 to 400 m, of time, by identifying an area that can be crossed in 10-15 minutes by foot, or of population from 200 to 1500. [8]

2.4. Block scale

This is the easiest scale to identify, as a block is defined by intersecting streets, and is possibly the oldest in history. In some cases a block and a building coincide, but the most frequent occurrence is that of a handful of buildings in the same block (either adjacent or separated).

The block scale is ideal to analyze the morphology of the buildings, especially as applied to the evaluation of energy requirements, which can be extended to the rest of the homogeneous neighborhood. For thermal calculation, the block scale often coincides with the building scale, with the study of elements such as density, volume distribution, compactness, and so forth.

2.5. Building scale

The standard definition of the various urban scales stops at the block, as the smallest urban unity: the further subdivision is that of the building, usually identified as a standalone construction. However, a building in the urban environment is its smallest component, and therefore can be considered as the lowest level of the scale pyramid.

The most notable aspect at the building scale is the switch in perspective: the building can represent the user of networks and services that are analyzed at higher scales, as a provider or a consumer; furthermore, it is a direct source and target of interactions with other buildings.

3. Stages of the urban retrofitting process

3.1. Developing the concept

After identifying the intervention area (in the district-neighborhood range as defined above), the first stage of the district retrofitting project is the development of a district retrofitting concept. The concept may be initiated top-down by local governments or municipalities, or as a private or community proposal, and the feasibility study itself may be funded by grants, owners or commercial advances. The concept development could be aided by advisors and planners actively using the FASUDIR IDST (Integrated Decision Support Tool). The methodology of FASUDIR supports the development of district retrofitting concepts in a structured and interactive way, allowing concepts to include the current state as well as viable retrofitting strategies, assessed through Key Performance Indicators.

The aim and goals are thus decided at strategic level, but shall be translated at building level with a multiscale top down approach. In a similar way, the current state could be estimated bottom-up from the buildings to the district or neighborhood, as illustrated in Figure 2 below. The strategies decided at one scale shall be verified to ensure coherence with the strategies at the other scales. Analyzing the problem at different scales will also increase the participation of stakeholders [9].

3.2. Refining the project

To progress the project after concept approval, the project initiators (typically, a municipality) will commission and finance a retrofitting management team of architects, engineers, urban planners and building contractors. The retrofitting management can be led by the same persons who planned the district retrofitting concept or additional experts, and funded from a mixture of sources including grants and loans.

The project shall thus be refined taking into account the specific circumstances of the building scale and could highly benefit from the link that already has been established in the concept defining phase between the scales. The strategy at urban scale could easily be translated to specific buildings and in the same way new detailed information about the buildings could be used to refine the strategies at urban scale, and KPI variations shall be monitored.

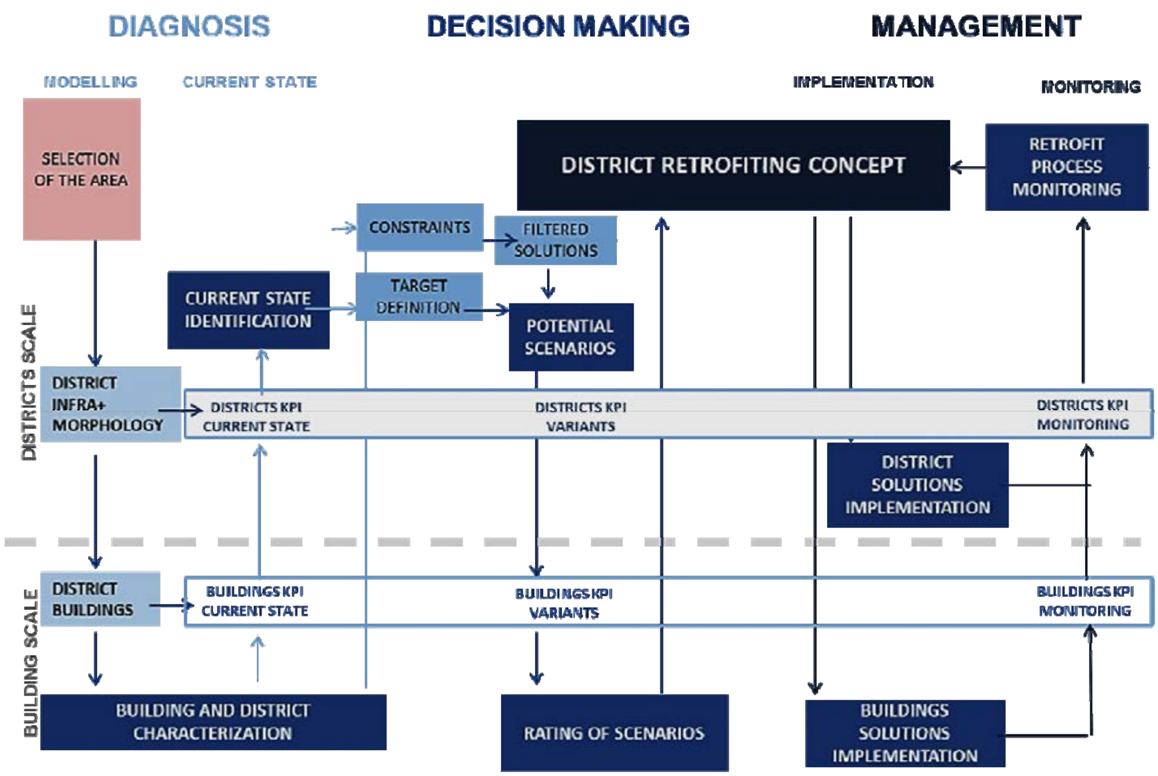

Fig. 2. FASUDIR multiscale framework.

3.3. Managing the project

The FASUDIR IDST is not specifically a management tool, but it will support the retrofitting manager during the retrofitting process including communication with the stakeholders. In this way, the IDST may be used to demonstrate possible retrofitting scenarios and already achieved successes from the district retrofitting concept, and the owners, users and ESCOs can provide data on completed retrofitting measures in order to update the retrofitting implementation process. The retrofitting manager will be able therefore to present the ongoing progress and achieved results to local governments/municipalities and compare it with EC and national guidelines; if the retrofitting process is not progressing as planned, the stakeholders can implement various contingency measures.

The implementation of the interventions included in the concept will generate updated, detailed information at building scale that shall be taken into account. Updating the model as the planning is implementing will allow the refinement of the whole retrofitting plan. The improvements achieved at building level and the KPI values they generated will be transferred at district scale to monitor the goals and overall KPI assessment.

4. Information flow

Urban models are digital environments used for testing the consequences of physical planning policies on the future form of cities. Therefore the urban modelling has to fall between the search for simplicity in articulating the structure of cities and the need to embrace the obvious complexity that confronts our understanding and intervention in such systems. [10]

The interscalar approach of the FASUDIR project has led to the selection of a strategy on the scale of information and to search for models that support computer-based multiscalar simulations. In case the main element of an urban scene is the building, where the level of detail of the information required is very high and refers to the buildings and their elements (typology, internal spaces, components, etc.), the proper approach for the representation of information is the Building Information Model (BIM). However, if the required level of detail of information is lower and such information will be used for decisions at strategic level, a suitable approach falls within the urban scale alternatives. As mentioned previously, FASUDIR is focused on the district to neighbourhood level. Therefore the urban scale is the most appropriate for the representation of project information, although is also necessary to have highly detailed information at building scale for decision making at urban scale. Thus, FASUDIR modelling again adopts a multi-scale approach for storing information to support sustainable energy assessment and management at district or neighbourhood level. The selected standard (CityGML [11]) supports different levels of detail (LoD), ranging from terrain (LoD0) to internal components of buildings (LoD4). The FASUDIR approach stops at LoD2, which differentiates building and roof shapes and separates envelope properties, sufficient to model the energy performance at building scale in a simplified but effective way.

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