3.2 SEMANCO: Semantic Tools for Carbon Reduction in Urban Planning

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Abstract

The goal of the SEMANCO project is to develop an ontology-based energy information system and associated tools that help stakeholders involved in urban planning to make informed decisions about how to reduce CO_2 emissions in cities. An ontology system is to be developed from the requirement analysis per-formed at the case studies. This approach enables data, services and stakeholders to be taken into account in the process of building ontologies. To create the ontology-based system we have adopted a decentralized approach according to which modular ontologies from diverse domains become interlinked through a semantic framework. In this paper we summarize the project vision and discuss some research issues currently being developed in the project concerning ontologies for energy information at the urban level, multi-scale analysis of carbon reduction problems and integration of GIS with linked data.

1 Introduction

1.1 Applying ontologies to energy information

During the last four years, we have been developing a line of research aimed at applying ICT to the modelling and analysis of energy information first at the building scale and later on at the urban level. In the IntUBE project carried out from 2008 to 2011 within the 7th Framework Programme, we have proposed an energy information integration platform (EIIP) to capture the energy information flow throughout the different stages of the whole building life cycle (Böhms et al. 2010). The platform was composed of four data repositories to store building, simulation and performance data generated throughout the different stages of the building life cycle An OWL ontology was created to model the data in each repository according to the knowledge provided by domain experts. Later on, in the RÉPENER project co-financed by the Spanish 2009-2012 National RDI plan, we have moved from the idea of an integrated platform to the creation of an energy information system which integrates both proprietary and open data, following the initiative of the Linked Open Data movement. In this project, we have created an energy model based on existing energy information standards which encompass building data as well as the contextual data –climate, economic and social– which impact buildings' energy efficiency. Based on this model, we have created local ontologies which integrate proprietary and public data and present the data on the Internet using RDF language (Madrazo et al. 2012). Lastly, in 2011 we started the SEMANCO project –also co-funded by the 7th Framework Programme– whose purpose is to apply semantic technologies to modelling energy information at the urban scale. In this paper, we will introduce the project's aim and discuss some areas of the research which are currently under development concerning the design of ontologies for energy data at the urban level, modelling of complex systems, and integration of GIS with linked data.

2 SEMANCO: the projects Aim

2.1 Project scope and structure

Continuing with the work we developed in the IntUBE and RÉPENER projects, the purpose of SEMANCO is to create a system of energy information using semantic web technologies which –unlike the previous projects– is not limited to buildings but extends to the urban scale. Specifically, the objective of SEMANCO is to provide methods and tools, based on semantic modelling of energy information, to help different stakeholders involved in urban planning to make informed decisions about how to reduce CO_2 emissions in cities.

- Supporting access to, and analysis of, distributed and heterogeneous sources of energy related data, both open and proprietary
- Semantic modelling of energy data according to energy and ontology standards
- Integrated tools that access and update the semantically modelled data, based on new and existing IT solutions for decision making in development of CO_2 reduction strategies
- An analysis of requirements to ensure that the tools and CO_2 reduction strategies developed address real world problems represented by the case studies.

2.2 Semantic Energy Information Framework

A key component of this research is the design and implementation of the Semantic Energy Information Framework (SEIF). This framework is the nexus be-tween the different data sources and the tools which use the semantically modelled data (Fig. 1). The semantic mapping will act as a bridge between different domains (city planning and energy provision) and contents (consumption data, pollution sources, simulated energy profiles and benchmarks). This semantic model will support interoperability among systems by enabling translation and mapping between different modelling methods and tools to support decision making in urban planning. Through the SEIF, a set of analysis and visualization tools to be developed in the project will access the heterogeneous and distributed databases containing different types of energy related information. This data integration is done with ontology matching techniques which are well-known and have proved to inter-relate heterogeneous data sources (Euzenat 2011).

Semantic data integration will require defining a local ontology for each data source. The SEIF implicitly contains an energy model which provides the necessary language to understand and interpret the complexity of different data sources and their inter-relationships. The energy model is implemented as a global ontology which embraces all terms that the tools need to interact with the SEIF. The energy model ontology and the local ontologies use the OWL standard language, and data is presented on the Internet using the RDF language following the Linked Open Data (LOD) initiative.

The terminology contained in the semantic energy model is based on international energy and environmental standards. Nowadays, ISO standards are all in terms of the building scale, and –to the best of our knowledge– there are no specific International Standards for energy modelling at the urban scale. However, starting from analysis at the building scale, the ISO standards also can be indirectly applied to urban energy modelling. This statement is confirmed by the majority of studies on urban energy modelling, which have been carried out based on energy assessments of reference (representative) buildings and then extrapolated through analysis to the urban area by applying statistical data (Brownsword 2005, Jones 2001 & Yamaguchi 2003).

Specifically, energy model terminology is specified in ISO/IEC CD 13273 (Energy efficiency and renewable energy sources), ISO/DTR 16344 (Common terms, definitions and symbols for the overall energy performance rating and certification of buildings), ISO/CD 16346 (Assessment of overall energy performance of buildings), ISO/DIS 12655 (Presentation of real energy use of buildings), ISO/CD 16343 (Methods for expressing energy performance and for energy certification of buildings), and ISO 50001:2011 (Energy management systems – Requirements with guidance for use).

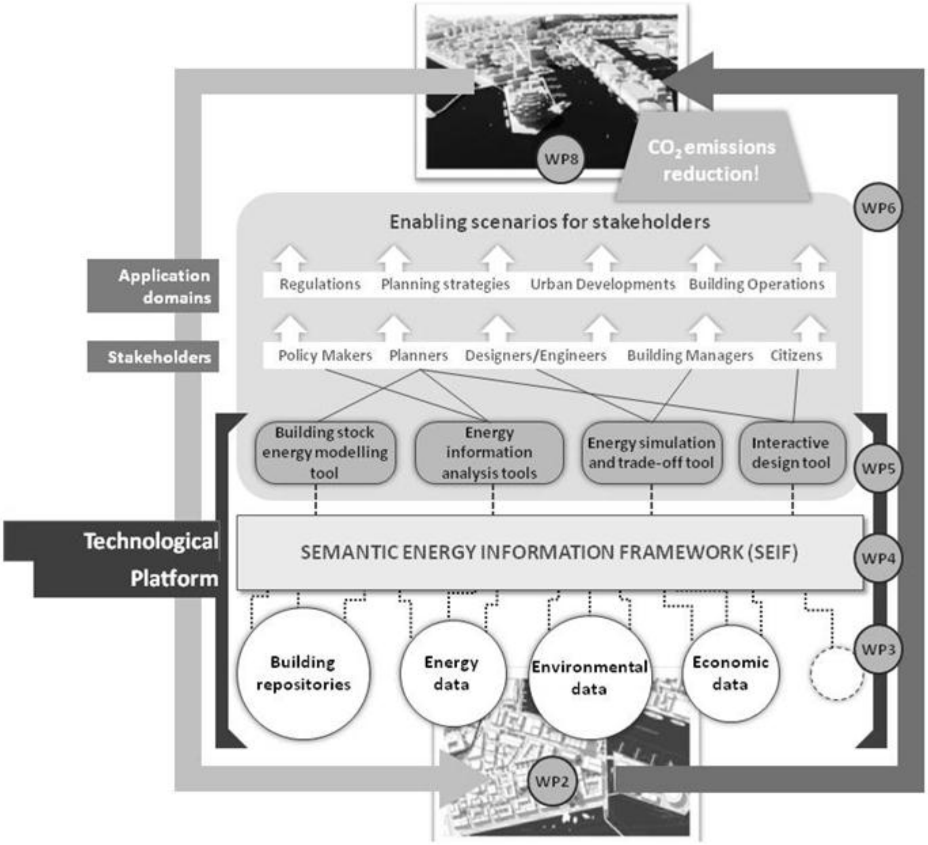

Figure 1. Structure of the SEMANCO project.

2.3 Integration of multiple scales

The problem of CO_2 emissions reduction is difficult to delimit to a particular geographical area. It is a systemic problem in which multiple dimensions and geographical scales need to be integrated. For instance, we can focus the description and analysis of an urban system on different scales: at building, neighbourhood, district or city level, among others. The existence of multiple scales conveys important challenges to be addressed in the analytical process concerning carbon emissions: the relevant aspect considered to perceive and represent the system would change depending on the chosen analytical scale. In order to address the multiple dimensions involved in the problem of CO_2 emission reduction, the tools and methods developed in SEMANCO will integrate the various geographic scales at different demonstration scenarios (Fig. 2).

Through the SEIF, the energy data associated with the different geographic scales will become inter-related (Fig. 3). The SEIF provides data that the analysis and visualization tools need for a specific task at a given scale. Conversely, the outcomes generated by these tools enhance the energy model implicit in the semantic framework.

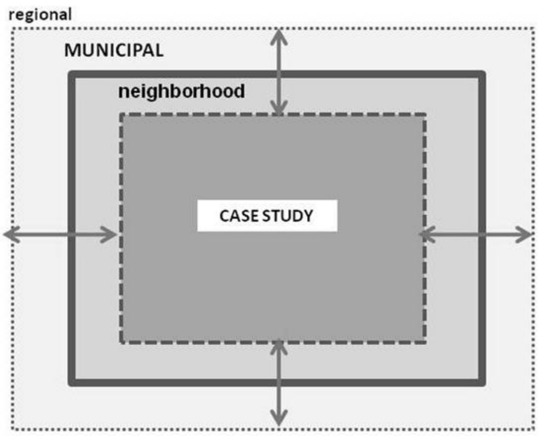

Figure 2. Integration of multiple geographic scales in the case studies.

2.4 Research methodology

The methodology adopted in the research is based on a case study approach. Different scenarios located in Denmark, Spain and the United Kingdom will enable delimiting the scope of the research and defining the specifications for the tools needed by stakeholders in different domains: planners working on the development of new areas or the renovation of existing ones; policy makers setting targets and regulations to reduce carbon emissions, and citizens applying energy efficiency measures in public and private buildings. Furthermore, the demonstration scenarios will help to:

1. Identify relevant indicators; interrelationships between factors contributing to CO_2 reduction; emission reduction strategies; baselines for energy consumption; and uses of energy efficient and renewable energy technologies;

2. Verify effectiveness of tools and methods; reductions of energy consumption and CO_2 emissions; social impact; improved indoor environmental qualities (IEQ); and investment costs.

In order to create the energy model embedded in the SEIF, it is necessary to compile a set of existing data sources and a set of tools which make use of the data within a limited application realm or use case. In the context of this research, a use case delimits a research problem concerning carbon reduction in a specific domain. The use case describes how actors, tools and data interrelate in order to fulfil a strategic goal.

3 Project development

In this section we discuss some of the project areas which are currently being developed regarding the creation of ontologies for energy information in urban environments, multi-scale analysis of energy systems, and integration of GIS and linked data.

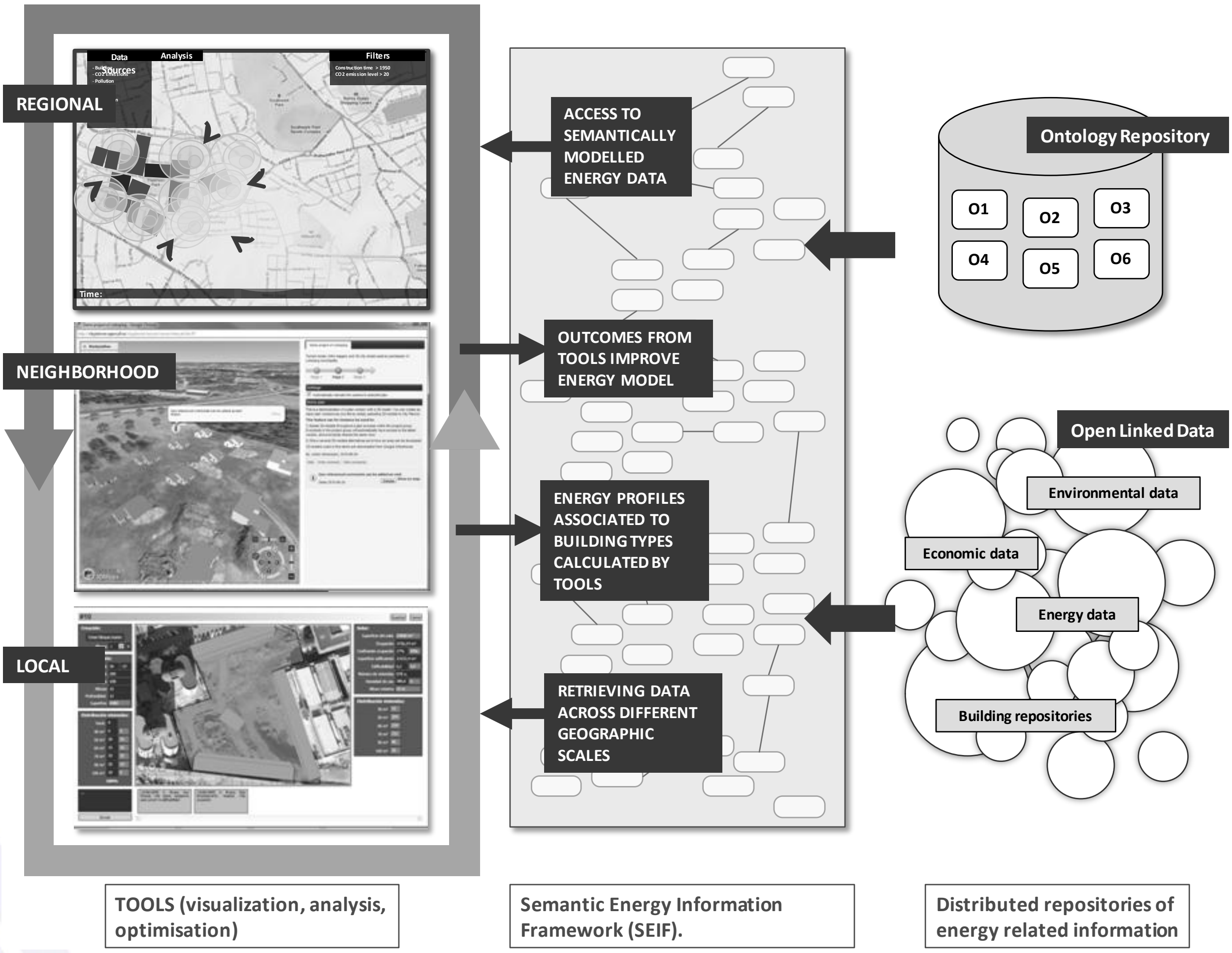

Figure 3. SEMANCO technological platform.

3.1 Ontologies for energy information in urban environments

As Guarino & Giaretta (1995) had explained, within the knowledge engineering community "ontology" refers to a particular object rather to a discipline (e.g. the philosophical notion of Ontology). This object can be thought of as an informal conceptual system, a formal semantic account and "an explicit specification of a conceptualization", as Gruber (1993) had defined it. Considering ontology from a technical point of view, a clear distinction should be made between "an ontology" intended as a particular conceptual framework at the semantic level and an ontology intended as a concrete artefact at the syntactic level to be used for a given purpose" (Guarino & Giaretta 1995).

In the context of the current level of development of the semantic web, ontologies make it possible to connect different views of the word fostered by different disciplines and domains which are embedded in the information structure of different data sources. More recently, the linked open data initiative has provided a new impulse towards the transformation of the web in a global knowledge base (Heath 2011).

3.1.1 ONTOLOGIES, ENERGY AND GEOGRAPHIC INFORMATION

Although in the recent literature we find applications of semantic technologies to specific domains related to energy efficiency in buildings –operation, interoperability, smart grid (Kofler et al. 2012, Noguero et al. 2011, Han et al. 2011, Kabitzsch & Ploennings 2011 & Wagner et al. 2010) – not much work has been done so far with regard to using the ontologies to integrate energy data from different domains in an urban context. Nor have we been able to find references to application of ontologies to represent the complex interaction between data from multiple domains –social, economic and urban– involved in the modelling and understanding of carbon emissions in urban environments. Further difficulties to be overcome have to do with difficulty obtaining the data that is necessary for energy efficiency research (Lannon & Linovski 2009).

The integration of urban energy models with GIS systems using ontologies, however, opens up an area of research which will require systems able to capture the relationships between buildings rather than the buildings themselves; the interaction between different levels of the built environment (between buildings and streets, for example); and changes over time (Lannon & Linovski 2009). Even though there are many environments to manage ontologies, so far they have not been dedicated to modelling of geographic information (Zaki et al. 2009).

3.1.2 ONTOLOGY DESIGN

Ontology design conveys a process of knowledge sharing between a community of users (domain experts, users of semantic-based applications) and ontology engineers. It also requires having access to existing data sources (proprietary and public) and defining the relationships between data based on the use that will be made of that data (by application services and different users). Adding semantic meaning to data, therefore, is inextricably related to the use that will be made of these data in a particular context. The case study approach adopted in the project brings together actors, data and services within a particular frame, which we refer to as "use case". This approach enables us to take into consideration the user's needs, in order to ensure that ontological systems are of use to different stakeholders involved in urban planning (Lannon & Linovski 2009).

The process of creating an ontology requires a certain methodology, and precisely this lack of established methodologies is one of the difficulties to overcome. As Gómez & Benjamins (1999) contended, "The ontology building process is a craft rather than an engineering activity. Each development team usually follows its own set of principles, design criteria and phases in the ontology development process." Because of this, the creation of ontologies is still a craft which requires specific strategies for each particular case. In the process we have started, users and domain experts formulate use cases which delimit a research problem describing how actors, tools and data are interrelated in order to fulfil a specific goal. Use cases are broken down into activities which in turn can be shared by different cases. Then, as the Neon methodology proposes (Suárez-Figueroa et al. 2012), the activities are described in form of requirements and competency questions to capture knowledge of the users and domain experts. Domain experts take into account the data sources and use cases to model a local ontology, guided by ontology engineers.

In the SEMANCO project we are creating a set of ontologies which respond to the requirements of the use cases and help to model the different data sources.

Energy data sources are usually stored in relational databases such as MySQL, SQL Server, or Oracle. In order to have integrated access to these heterogeneous sources, a data integration process needs to be carried out. According to the semantic web community, the relational data should be complemented with semantics. This process involves a mapping from the relational database to the datasets, and implies a transformation of the relational data into an RDF expressed in an ontology which has been previously defined.

The first step of the integration process is to design local ontologies which match the data sources. The methodology applied to the creation of the local ontology follows design patterns which ensure compatibility with the energy model which is implemented as a global ontology. In particular, the application of these patterns ensures that: 1. A local ontology uses the terms that are defined in the energy model, 2. The local ontology reuses data structures from the energy model (e.g. adding standard units to a data type property such as distances or measures), and 3. The integration of new data sources can improve the energy model, adding new terms and relationships which might be needed by new use cases.

Once a local ontology has been created for each data source involved in a particular use case, the next step is to transform the relational data into RDF format, which is the standard to describe resources on the Internet. A survey published by W3C RDB2RDF incubator group has identified several tools to make this transformation such as Virtuoso RDF View, D2RQ, R2O, RDBToOnto, or Dartgrid (Sahoo 2009). The survey states that there is not a standard method for representation of mappings between RDB and RDF and, whenever possible, it is better to implement on-demand mapping to access to the latest version of the data. The RDB2RDF group is currently working on the first conclusions regarding the R2RML language recommendations dated February 2012, which are being implemented by some projects at this time.

3.1.3 ONTOLOGY MAPPING TOOLS

As part of the SEMANCO project, we have started to develop tools which help users – domain experts and ontology engineers– to integrate data collaboratively using standard semantic technologies. These tools facilitate the design of ontologies by enabling users to work together in the same environment and to automate parts of the process, such as mapping file creation according to an ontology. We have not found an existing tool which fulfils all these requirements. Therefore, we have started to implement our own tools based on the D2RQ platform (Bizer 2007). We have decided to use this platform because it provides a language which supports on-demand mapping and also can provide complete RDF datasets; it performs well because it rewrites the SPARQL queries into SQL; it is a stable and light-weight solution; mappings are represented with D2RQ mapping language which is easily customizable; and it is currently developing a version which supports R2RML.

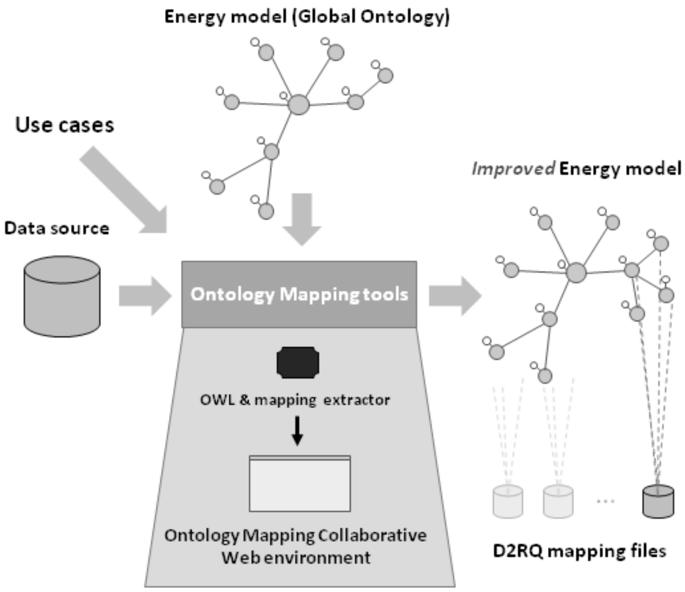

Figure 4. Ontology mapping tools. Inputs and outputs.

The inputs of the ontology mapping tools are the use cases (provided by the users), the current version of the energy model, and a data source. The outputs are an improved version of the energy model and a mapping file which transform relational data into RDF. The ontology mapping tools which are being developed are an OWL and mapping extractor and an ontology mapping collaborative web environment (Fig. 4).

The goal of the OWL and mapping extractor is to automatically generate a local OWL ontology file and a D2RQ mapping file. The tool is configured defining the database connection parameters. Additionally, the user selects which columns would need units. The tool reads the database structure and, following the design pattern mentioned above, generates the output files. This tool is being developed in Java as a command line program in which configuration parameters are given by command line.

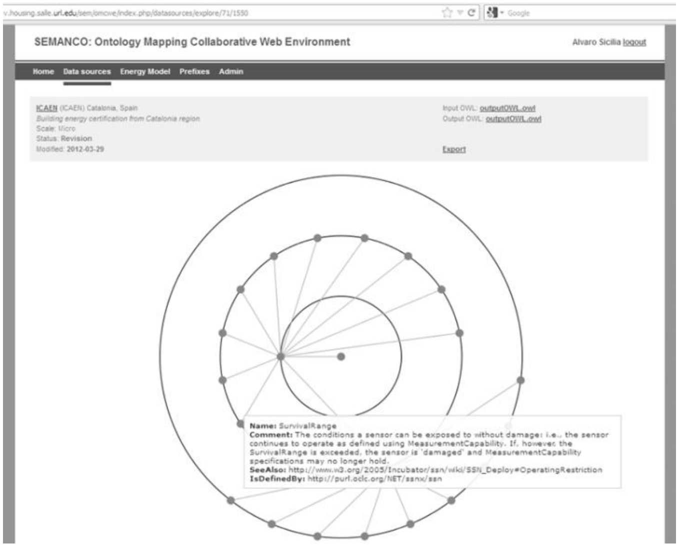

Figure 5. Ontology mapping environment.

The ontology mapping environment facilitates the collaborative work of domain experts and ontology engineers to integrate a local ontology into the energy model (Fig. 5). Once the user has uploaded the files generated by the extractor, he or she can view the list of terms of the local ontology. Furthermore, a user can redefine the source terms by selecting a term of the energy model or providing a new one. In the case of new terms, users supply super-terms to connect them to the energy model. In this collaborative environment, users can track the activity of their colleagues and also comment on their actions. Finally, users can export the work done, generating an OWL ontology. This ontology is a portion of the energy model. Each time a data source is integrated, the energy model grows, embracing new terms and properties. The front-end of this environment is being developed in HTML, Javascript and CSS. CodeIgniter framework for PHP is used for the logic layer and MySQL for the database. Some free PHP libraries have been used such as ARC2 and the JITG.

3.2 Multi-scale analysis of urban energy systems

3.2.1 URBAN ENVIRONMENT AS COMPLEX SYSTEM

From a physical point of view, we can think of the urban environment as a hierarchical system in which, for example, buildings are grouped in neighbourhoods, neighbourhoods in cities, cities in regions, and so on. From this point of view, an urban area is a complex system made of smaller systems each consisting of a set of elements which work with each other in a certain way. However, as Alexander contended in his text *The city is not a tree*, published in 1966, when the urban environment is considered as phenomena rather than as physical objects, there are many more relationships occurring which cannot be represented as a simple hierarchical structure like a tree but with the more subtle and complex structure of a semilattice. On the other hand, Koestler, in his book *The Ghost in the Machine* from 1967, contended that in complex systems such as living organisms and social organizations, the elements making up the hierarchy are at the same time part and whole. He coined the term "holon" to reconcile the atomistic and holistic approaches. According to Koestler, holons are defined by fixed rules and flexible strategies. Therefore holons are not well-defined components, but rather relative positions within a system of relationships which help to understand certain aspects of reality.

These views about the urban environment and the structure of complex systems, formulated almost fifty years ago by Alexander and Koestler, are worth being reminded of as we start to address the problem of modelling energy systems at the urban scale. Let's consider, for example, an energy system as a holon. On the one hand, it has to maintain coordinated operation between holons of the same level of the hierarchy. In practical terms, that means that the energy sector has a) to keep control of the elements comprising it (e.g. to assure coordinated operation between energy transformation plants, transport and distribution systems), and b) to "compete" with other socio-economic sectors for the resources needed to perform its tasks. Examples of those required resources are the necessary human activity (e.g. requirements of skilled labour) and land (e.g. whether to construct a wind-farm or to conserve the cultural landscape heritage to foster eco-tourism). On the other hand, the energy sector has to fulfil some specific functions expected by the upper-level elements of the hierarchy. In this case, it has to deliver a certain mix (in amount and quality) of energy carriers required by the rest of the society. That is, a holon should have coordinated interaction both with elements of the same level of the hierarchy (horizontal coupling) and elements of different levels of the hierarchy (vertical coupling) (see Giampietro et al, 2006 for a detail description of these concepts).

All of these activities take place in the "system energy" and in the physical space which supports it. This leads us to the discussion of the definition of the spatial boundaries of the system under analysis.

3.2.2 SPATIAL BOUNDARIES

Along with the notion of the urban environment as a complex system which encompasses the physical space as well as the activities taking place in it, we need to consider the issue of the system's spatial boundaries and geographic scale. At the outset, we can think of a spatial boundary in two ways: one which considers space as a set of relationships and the second which thinks of space as a container (Fig. 6). In Figure 6a, the former is represented by a dynamic flexible boundary which might be determined by the interactions between the elements of the sys-tem (between data, between stakeholders, between factors influencing CO2 emissions). Space as a container is presented in Figure 6b as an established boundary determined by administrative reasons (a neighbourhood, county, region etc.) which might vary from one country to another.

On the one hand, we have areas and regions with dynamic and flexible limits: limits that are determined by the interactions between identified elements of the system (e.g. the system by which the problem of CO2 reduction is conceptualised). On the other hand, there are areas and regions that have established limits, such as administrative regions. These areas/regions are also decision-making domains, for instance, at the political and administrative levels. This is the case for districts/wards, cities, municipalities, provinces and so on. However even these "static" boundaries can be flexible and dynamic. For instance, laws and policies defining boundaries of action may change over time: new laws may redefine the administrative boundaries, and urban planning schemes may change their conception of spatial scales to incorporate these changes. In SEMANCO, we need to integrate and make compatible both notions of space.

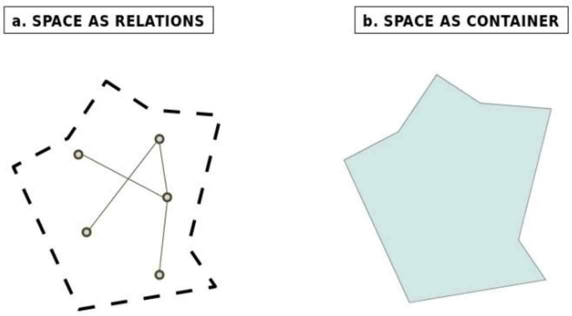

Figure 6. Understanding spatial boundaries as relations or as container.

3.2.3 ACCOUNTING FRAMEWORKS

Another important consequence of dealing with complex systems operating at multiple scales is the need for an adequate accounting framework to develop and assess a robust set of performance indicators across scales. A system has certain properties and behaviours that are not possessed by any of the individual parts making up the whole. The opposite also applies: there are emergent properties of the parts which conform to the whole that are not possessed by the system as such. For instance, urban lighting systems are important components of the system at the neighbourhood and city levels. At these levels, the energy accounting system should consider the energy consumption of the urban lighting systems, which may become irrelevant in the analysis of the energy performance of a building. In fact, the requirements of human, economic and technical resources needed for the functioning of the public lighting system are usually covered by a municipal company or a public utility which operates at the neighbourhood and city level. As the identity of the system depends on the scale of analysis, we can expect different values for the same indicator evaluated at different scales (e.g. the electricity consumption per capita may vary if we carry out the calculation at building or neighbourhood level). The important thing here is that we need an accounting framework allowing the analyst to scale the information up and down, producing coherent results across scales (e.g. if the electricity consumption per capita varies if calculated at building or neighbourhood level, then the accounting framework and the aggregation method should produce different values).

The Multi-scale Integrated Analysis of Societal Metabolism (MuSIASEM) developed by Giampietro et al. (2009) is an analytical framework explicitly dealing with the issue of multiple scales. It also provides a flexible accounting framework that allows coherent assessments across scales.

MuSIASEM relies on the concept of the holon in order to perceive and represent the system under analysis. We can represent a city using several lower-level compartments, such as residential and non-residential areas, which can be further split into lower-level elements. For instance, a residential area can be split in different neighbourhoods, which in turn conform to building typologies (e.g. residential, schools, offices and hospitals, among others), the street network and other urban elements.

This approach provides a flexible accounting framework whose categories can be tailored according to the objectives of the analysis. For instance, we can distinguish high and low-income residential areas in order to perform a specific analysis based on the socio-economic conditions of the inhabitants.

Then, the assessment of the performance of the system is based on the fund-flow model developed by Georgescu-Roegen (1971). Fund categories describe what the system is (e.g. capital, people, Ricardian land) and flow categories describe what the system does (e.g. added value, water, energy, matter). On the time scale of the representation, funds transform input flows into output flows, and flows are either consumed or generated in order to reproduce the funds categories.

Following this approach, we can aggregate funds and flows categories of lower-level elements in order to assess the performance of an upper-level element. In the same way, we can disaggregate variables of an upper-level compartment and assess the performance of its components. The assessment is complemented by using intensive indicators: flow/fund or fund/fund ratios to describe the pace of the metabolism of the compartment under analysis (e.g. flow of energy carriers per square meter, measured in kWh/m2). They describe how the system does what it does. For instance, if we disaggregate the consumption of electricity of the elements making up a neighbourhood (residential buildings, public services, office buildings, street lighting and other urban elements) and the surface used by those compartments, we can identify those elements with levels of consumption per square meter that are above the expected or reference values (i.e. benchmarks).

Summarizing, we can say that the ability of the MuSIASEM approach to defining analytical categories according to the objectives of the analysis might be mutually complementary with the flexible (semantically modelled) data structure provided by SEMANCO's semantic framework. Also, it provides adequate flexibility to deal with the different conceptualization of space mentioned above. Finally, it provides an accounting framework to scale information up and down, producing coherent performance indicators across scales.

3.3 GIS and semantic data

Typically, a GIS software represents the built environment according to the structure required by a particular organization (a transportation agency, a real estate company). In doing so, for GIS the built environment is a fixed structure rather than a complex system of interrelationships. As Kuhn (2000) had claimed, "GIS should support human activities. Instead, they are often designed as passive models of the work, with too little concern for the task contexts in which they will be used". The view of the world that GIS provide would have "less to do with human activities than with existing data holdings". According to Kuhn, the use of ontologies would make geographic information systems more useful and usable, with a focus on human activities.

To facilitate the exchange of data across multiple GIS systems –and, indirectly, across multiple views of the built environment– the Open Geospatial Consortium has promoted the CityGML standard. The standard is based on the OGC GIS standard GML 3.0 and offers a way to describe most (or all) needed characteristics of a 3D city model as GML features and geometry in a standardized XML document.

Even though CityGML claims to take into consideration not only the geometric properties of objects but also their semantics, there are some doubts about the capacity of the language to represent the semantics of urban information. In particular, CityGML might be insufficient to represent information in urban projects involving multiple actors (from citizens to specialists in different fields) and multiple tools such as plans, legal texts or 3D representations (Métral et al. 2009). To overcome these limitations, additional ontologies have been connected to the CityGML ontology. Montenegro (2012) has proposed a land use ontology which is the core of 4CitySemantics, a tool for city planning which assists participants in the urban development process. In the OUPP and CALAKMULL projects, ontologies have been used to interconnect models representing different views of the urban environment with CityGML (Métral et al 2009). Further-more, adding ontologies to CityGML can also help to model not only the entities constituting a geo-graphic space but also the actions that take place within particular domains (Camara et al. 2000, Smith 2000 & Kuhn 2000). As a result of the current trend towards integrating linked open data using modular ontologies, the original central position of CityGML as a standard to exchange geographic data might change. In this context, CityGML would become one more source of data to relate to other data (Ronsdorf 2011).

In line with these approaches, SEMANCO aims at integrating geographic data in CityGML format with other kinds of open data using semantic technologies. This way it would be possible to bring together the different kinds of data –from different domains, geographic scales and applications– that are needed to model an energy system, and to apply the appropriate evaluation and multi-scale analysis techniques required in particular use case.

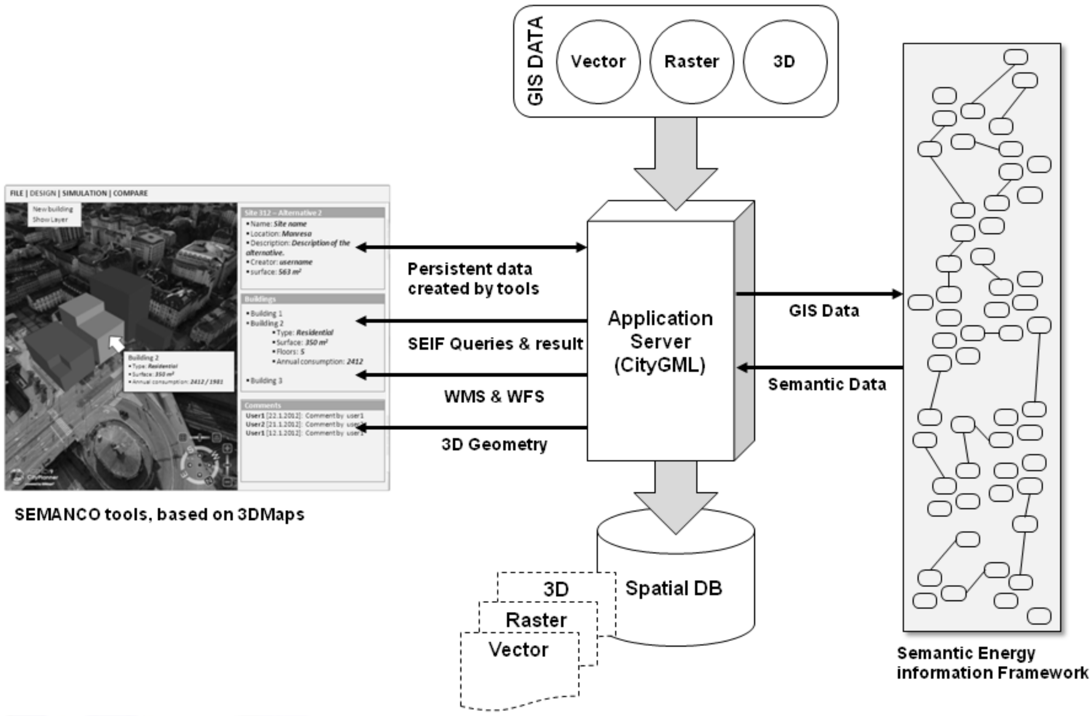

Figure 7. Integration of the SEIF with 3dMaps GIS software.

3.3.1 GIS SYSTEM 3DMAPS

The semantically modelled data facilitated through the SEIF will be used by stakeholders at different decision-making domains and by different applications integrated in 3dMaps GIS software from Agency9. This is a rich web platform with a JavaScript enabled API to handle most use cases from simple editing to rich visualization and user interaction. The platform also offers a set of tools to automatically create 3D maps from aerial photography, DEM/DTM, WMS and WCS data, as well as tools to process and optimize large batches of 3D models to be served from an HTTP cache.

Figure 7 shows the integration of the SEIF with the visualization tools integrated in the 3dMaps software. An application server will have the task of managing import and export of GIS and semantic data to the platform, populating the spatial database with GIS data and maintaining the 3D web cache with updated optimized data. This server will also facilitate the different tools implemented for the data in the SEMANCO project and provide a layer for interoperability between the tools. The storage of GIS data and persistent data created by the tools will be handled by a Spatial Database. The Application server stores and fetches data when needed from the Spatial DB. The 3D data could be stored in a structure similar to 3D City Database in order to use the OGC standard CityGML internally as well as for input and output to the platform.

4 Conclusions

In the SEMANCO project we have adopted a comprehensive approach to modelling energy information at the urban scale using ontologies. In this context, ontologies would help: 1. to integrate data at multiple geographic scales; 2. to capture domain expert knowledge; 3. to interrelate different domains involved in the evaluation of CO_2 emissions; and 4. to exchange data generated by various applications (interoperability across GIS, simulation programs, and sensor systems).

The decentralized approach based on interlinked semantic databases driven by the linked open data community is one of the pillars of the SEMANCO project. The purpose is to make use of a net of inter-connected standards (e.g. CityGML, ISO/IEC CD 13273, ISO/DTR 16344) rather than placing a particular standard at the core of the energy information system. In this context, our goal is to create expressive ontologies –rather than vocabularies– to model data as well as perform data analysis and inference processes.

In order to build the ontologies, we have adopted a methodology based on the integration of data sources, services and actors around a particular use case. A use case provides the specifications necessary to design the ontologies, while it ensures that the data and analysis processes will be of use for a particular group of stakeholders in the actual world.

Ackowledgements

SEMANCO is being carried out with the support of the Seventh Framework Programme “ICT for Energy Systems” 2011-2014, under the grant agreement Number 287534. We would like to thank our colleagues in the project consortium for the assistance provided to prepare this document: Ilaria Ballarini and Vincenzo Corrado, from Politecnico di Torino, for the information on energy standards, and Johan Göransson and Tomas Karlsson, from Agency9, for the descriptions of 3dMaps software.

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