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SEMANCO

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5	2014-5-26	Pamela Hadida (FUNITEC)	Linguistic review
6	2014-5-31	David Lynch (NEA)	Proof-reading

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EXECUTIVE SUMMARY

This report summarizes the presentations and discussions held during the 4th Vocabulary Camp (VoCamp) on "Integrating multiple domains and scales", which took place at La Salle Engineering and Architectural School in Barcelona, from 13th to 14th February 2014, organised by the SEMANCO project.

The VoCamps series is an initiative of the European Commission carried out with the support of the ADAPT4EE project. According to its original intention, a VoCamp is an informal event where experts meet to deliver lightweight vocabularies and corresponding ontologies for the Semantic Web (Web-of-Data). The goal of every VoCamp is to bring together 20 to 30 experts to discuss the state of the art about a specific topic and to come up with a proposal for new or enriched vocabularies.

The purpose of this VoCamp was to discuss the application of ontologies to integrate data from various domains and scales to improve the energy efficiency in urban areas. Urban planning, and in particular the adoption of measures to improve the energy efficiency at the urban level, involves the participation of experts from economics, urbanism, architecture and engineering, among other disciplines. Issues concerning the energy efficiency of urban areas – for example, reducing carbon emissions, improving the energy efficiency of the building stock, optimising the transport network or reducing energy consumption in public lighting – involves addressing problems at various scales – building, neighbourhood, district, region – simultaneously. In this context, the assumption is that ontologies are suitable knowledge representation mechanisms to create models which integrate the various disciplines and the multiple scales involved in the creation of models of urban energy systems. This helps stakeholders involved to take decisions aimed at improving the energy performance of urban areas.

Two keynote speakers were invited to provide a perspective on two key issues related to the application of ontologies to model urban energy systems. Koen van Dam, from the Imperial College in London, presented the next generation tools and infrastructures that will enable cities to become smarter, digitized so that they can offer new enhanced services to its citizens; and Claus Nagel, Head of Software Development at the company virtualcitySYSTEMS GmbH, presented an overview of the CityGML standard.

The workshop program was structured around three interrelated issues:

1. Urban Energy Systems: determining the boundaries and objectives of urban energy systems.
2. Data Sources: representing objects and properties in urban energy systems
3. Visualisation: combining different visualisation models to facilitate knowledge elicitation processes

These issues were discussed in thirteen presentations delivered by representatives of five research projects (SEMANCO, Ready4SmartCities, NRG4Cast, COOPERaTE and Odysseus) which are dedicated to the application of ontologies in the field of energy efficiency. From these presentations, a range of topics was identified as relevant issues to take into account in the subsequent research work:

1. Agreement on the basic terminology. In many presentations, questions were raised about the shared meaning of some recurrent terms such as model, metamodel, semantics, metadata, vocabulary, ontology and urban energy system.

2. Ontology building: methods and tools. The ontologies and models that were presented during the VoCamp were developed with different tools. Some developers used Protégé (or its web version) to create the ontology in a collaborative manner with domain experts. The difficulty for non-ontology experts to use this kind of tools was pointed out.
3. Ontologies and their relations with existing standards. The relation between the ontologies created by research projects with the existing standard data models (IFC, CityGML) was discussed. Two distinctive, although complementary approaches, were identified: a universal approach which aims at solving "all" application cases (e.g. standard data models), or a particular approach dealing with every application separately (e.g. combining linked data with ontologies).
4. Technologies for data integration: ontologies vs. data fusion. Semantic technologies and data fusion are two distinctive solutions to integrate data which can benefit from each other's strengths. Data fusion and analysis can exploit the results provided by the application of ontologies and ontologies can be created from the results of the data analysis.
5. Smart city: activities vs. physical models. To create a model of a city (or, by the same token, of a building), it is necessary to consider both the physical objects and the processes that take place in them. Ontologies need to be used not just to describe "what is there" (objects and actors) but also to capture "what is happening there", that is to say, the activities that are taking place (actions and goals). Ontologies could be a suitable technology to model the interactions between socio-technical systems and physical systems.
6. Multiple scales and levels of details: aggregation through scales, city metabolism. The problem with having different models with multiple levels of detail is the integration of all of them in a single model. A seamless connection across multiple scales would enable the aggregation of indicators from lower scales onto upper ones and conversely (scaling up and down). Ontologies can help to integrate multiple data models with different levels of detail.

Some of the conclusions drawn from the discussions held during the sessions are the following:

- Ongoing efforts of standardisation bodies (BSI, CEN, INSPIRE, CBNL, etc.) shall be taken into account including ongoing activities on Smart Appliances in W3C Working Groups.
- Although they are strongly related, data standardisation is not exactly the same as ontology modelling.
- It is necessary to have transparency in the sharing of knowledge across end-users in the domain addressed in the VoCamp.
- Community support is necessary to facilitate the exchange of knowledge and experience among the developers of ontologies in the domain of smart cities and urban planning.
- Beyond the representation of the city as a "static" model, it is necessary to model also the city dynamics: what happens in the city and with what purposes, which actors are involved.

- It is necessary to have ontologies which support the creation of urban models that take into consideration both, the physical infrastructures and the activities that take place within the urban areas.

1 INTRODUCTION

1.1 Purpose and target group

This document summarizes the work carried out in the VoCamp on "Integrating multiple domains and scales" which took place at the School of Architecture and Engineering La Salle, Barcelona, Spain on 13th to 14th February 2014. The target group are experts in the application of semantic technologies to energy efficiency, ontology engineers, and in general, researchers working in the field of smart cities.

1.2 Contribution of partners

A first draft of the minutes of the meeting was compiled in a document jointly produced by Dimosthenis Ioannidis, from CERTH/ITI, Leandro Madrazo and Álvaro Sicilia from FUNITEC. Participants were invited to contribute to the minutes and to the summary prepared by the editors. Contributions were received from the following participants: Michel Böhms, Fabian Cretton, Koen van Dam, Markus Look, German Nemirovski, Pieter Pauwels, Maria Poveda, Tomi Räty and Matthias Weise.

1.3 Relations to other activities in the project

The VoCamp has been an opportunity to present the work done in the SEMANCO project to a group of experts working in the application of semantic technologies in different domains related to urban planning. The ontology design methodology devised in the project was presented, and the process which has been followed in the SEMANCO project – starting from an informal shared vocabulary and ending up with a formal vocabulary, i.e. ontology – explained.

2 THE VOCAMP SERIES

VoCamps (Vocabulary Camps) is an initiative of the European Commission carried with the support of the ADAPT4EE project. A vocabulary camp (VoCamp) is an informal event where experts get together to deliver lightweight vocabularies and corresponding ontologies for the Semantic Web (Web of Data). The goal of a VoCamp is that 20-30 experts discuss the state of the art about a specific topic and come up with a proposal for new or enriched vocabularies.

Until now, four of the six VoCamps that were planned for the period of 2012-14, have taken place:

- 1st VoCamp, 15-16 November 2012. Energy Efficiency Modelling. Organised by CERTH/ITI, Thessaloniki, Greece.
- 2nd VoCamp, 14-15 February 2013. Building Information Models (BIM). Organised by the European Commission, Brussels, Belgium.
- 3rd VoCamp. EupP (Energy using and producing products) Management. Organised by DFKI, Kaiserslautern, Germany.
- 4th VoCamp, 13-14 February 2014. Integrating multiple domains and scales. Organised by ARC Engineering and Architecture La Salle (FUNITEC), Barcelona, Spain.

This document summarizes the program and objectives of the 4th VoCamp, the presentations delivered by participants and the outcomes of the discussions.

3 VoCamp Programme and Objectives

3.1 Motivation

The topic to be addressed in the 4th VoCamp "Integrating multiple domains and scales" is the application of ontologies to create models of urban energy systems which helps the multiple stakeholders involved to understand the underlying problems concerning energy efficiency in urban areas and to take decisions to improve it.

Urban planning, and in particular energy efficiency at the urban level, involves the participation of experts from various disciplines – economy, urbanism, architecture, engineering – who need to share a common view of the issues concerning the city's development. This means that a city, considered as a physical ensemble amenable to be modelled, cannot be described univocally. Instead, it needs to be considered as a multidimensional artefact whose components can be interrelated in multiple views, depending on the issues at stake.

Furthermore, any issue concerning the energy efficiency of urban areas – for example, reducing carbon emissions, improving the energy efficiency of the building stock, optimising the transport network and reducing energy consumption in public lighting – involves addressing issues at various scales – at the building and neighbourhood level, at the neighbourhood and district level, etc.

Lastly, a city is not just a physical artefact which can be geometrically modelled, but also a space for action. The physical infrastructure of the city – buildings, roads, communication networks – provides the support for the flow of persons, vehicles, energy, assets and information. The activities that take place in the city are closely intertwined with its physical components.

Based on the previous considerations, a working programme was proposed by the group in charge of the organisation of the VoCamp – ARC Engineering and Architecture La Salle – based on the following assumptions:

1. The problem of energy efficiency in urban environment needs to be addressed at the system level: it is a systemic problem involving multiple actors, domains, scales and data. Hence, the assimilation of an urban area to an "urban energy system".
2. To understand how an urban energy system functions, models are needed. A model can be created for different purposes: to integrate data from various sources, to understand the behaviour of a reality as captured by the model and to predict future behaviour of a system.

Based on these premises, the role that ontologies could play; for creating and reusing models of urban energy systems; was formulated in these terms:

1. Ontologies imply creating a vocabulary shared by experts in a given domain. In the case of urban energy systems, multiple domains need to be considered (energy demand and supply, socioeconomic impact, legislative framework, building, transport, among others).
2. An ontology is created with a purpose in mind; it is an instrument to solve a problem. The problem delimits the scope of ontology. What an ontology is (the knowledge that is formalised with it) and what it is for (its purpose) are intertwined.
3. A model represents a reality as observed by domains experts based on the information

they have at some point. This information is processed with the techniques and methods of their disciplines. From this point of view, the difference between a “model” and an “ontology” starts to blur.

4. A model created as ontology is not only a representation of the observed reality, but a formalisation of the interpretation of the knowledge engineer about the knowledge that experts from different domains have about a complex problem related to energy efficiency. It is not a model of reality, but a model of how we think about a particular reality (that is, a metamodel or a cognitive model).

3.2 Programme

The goal of the VoCamp is to gain an understanding about the application of ontologies to integrate multiple domains and scales in order to develop models of urban energy systems, which help different actors – urban planners, consultants, policy makers, and dwellers – to make better-informed decisions to reduce energy consumption and carbon emissions in urban areas. In this context, the construction of a shared vocabulary can be understood as a process by which the knowledge from the different experts participating in the formulation and solution of a problem is formalised by means of the ontologies. Likewise, an urban energy system encompasses multiple scales that become intertwined because of the system’s activity. The relationships of system’s elements across scales can be also formalised by means of ontologies.

These three interrelated issues were proposed to be addressed by the participants in their presentations:

1. Urban Energy Systems: determining the boundaries and objectives of urban energy systems.
2. Data Sources: representing objects and properties in urban energy systems
3. Visualisation: combining different visualisation models to facilitate knowledge elicitation processes

A template to make a presentation of their research work focused on one of the three proposed topics and their interrelationships.

In addition, the following references were provided as reading material before the meeting:

Publications

G. Nemirovski, A. Nolle, Á. Sicilia, I. Ballarini, V. Corrado (2013) Data Integration Driven Ontology Design, Case Study Smart City. In *Proceedings of the 3rd International Conference on Web Intelligence, Mining and Semantics (WIMS).* Madrid, Spain, June 12-14, 2013.

G. Gröger, L. Plümer (2012) CityGML – Interoperable semantic 3D city models, *ISPRS Journal of Photogrammetry and Remote Sensing* 71, 12–33.

R. Kaden, T. H. Kolbe (2013) City-Wide Total Energy Demand Estimation Of Buildings Using Semantic 3d City Models And Statistical Data. In *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume II-2/W1, ISPRS 8th 3DGeoInfo Conference & WG II/2 Workshop, Istanbul, 27 – 29 November 2013.

D. Birch, O. Tsinali, K. H. van Dam, C-H. Lee, D. Silva, C. Wu, M. Ghanem, Y. Guo (2013). In *Proceedings of Concinnity: A Digital City Exchange Platform. Digital Economy Conference*, University of Salford, UK:

S. Acha, K. H. Van Dam, N. Shah (2013). Spatial and Temporal Electric Vehicle Demand Forecasting in Central London. In *Proceedings of 22nd International Conference on Electricity Distribution (CIRED)*, Stockholm, 10-13 June 2013.

SEMANCO Deliverables

- SEMANCO D3.2 Report on Guidelines for Structuring Energy Data
- SEMANCO D3.3 Guidelines for Structuring Contextual Data
- SEMANCO D4.2 Semantic Energy Model
- SEMANCO D5.4 Prototype of the Integrated Platform

4 Discussion topics

The following section summarises some of the topics that have emerged from the presentations given by the participating experts, and the discussions that followed.

The following topics have been identified from the presentations summarised in section 5:

1. Agreement on the basic terminology
2. Ontology building: methods and tools
3. Ontologies and their relations with existing standards
4. Technologies for data integration: ontologies vs. data fusion
5. Smart city: activities vs. physical models
6. Multiple scales and levels of details: aggregation through scales, city metabolism

4.1 Agreement on the basic terminology

In many presentations, questions were raised about the meaning of some recurrent terms. Model, ontology and vocabulary, for example, are terms whose meanings are sometimes exchangeable.

The following meanings of these recurrent terms have been identified as a result of the discussion:

- ***Model:*** A simplified representation of (a part of) reality, which satisfies certain formal constraints (model theory) and that can be used to assist in information processing tasks (simulation, visualisation, among others). A model is essentially a reduced or abstracted representation of the original system in terms of measure, precision and functionality[1]. It has several features, such as: mapping feature (a model is based on an original), reduction feature (a model only reflects a relevant selection of the original‘s properties), and pragmatic feature (a model needs to be usable in place of the original with respect to some purpose)[2]. Typically, computational models allow one to calculate the outcomes of various scenarios, but it can also be a diagram with boxes and arrows if the purpose is to explain something or design software, for example.

- ***Metamodel:*** The underlying meta-concepts by the language used to model data structures like ontologies and schemes. A metamodel defines the elements a model can use and its structure. It, therefore, provides a more generic and abstract definition. For example, the grammar of a language is a metamodel for the spoken or written language (e.g. the model), describing, in this way, a reality. The distinction between a metamodel and a model is considered superfluous and it is sometimes avoided: a metamodel is a model.

- ***Semantics:*** The shared meanings of words and phrases in a particular context. Semantics defines exactly the meaning of every element of a model in a context. We can distinguish between semantic domain and a semantic mapping. There are several approaches to define semantics: denotational, operational and translational. In a language, semantics goes beyond structure, expressed by a grammar, and beyond the context conditions. At least, we can identify two different levels of semantics referring to:

[1] Stachowiak, H. (1973) Allgemeine Modelltheorie, Wien: Springer.

[2] Kühne, T. (2005) What is a Model? Language Engineering for Model-Driven Software Development, Dagstuhl Seminar Proceedings. Internationales Begegnungs- und Forschungszentrum fuer Informatik (IBFI), Schloss Dagstuhl.

• Modelling objects having relationships and properties. This is what mostly concerns the creation of semantic models of buildings and cities.

• Modelling geometric representations of these objects, such as Boundary Representations and 3D Alignments as, for instance, the geometry descriptions of BuildingSmart IFC on the BIM-side and GML on the GIS-side. Description logics (DLs) are "a family of knowledge representation languages that are widely used in ontological modelling... they are equipped with a formal semantics: a precise specification of the meaning of DL ontologies. This formal semantics allows humans and computer systems to exchange DL ontologies without ambiguity as to their meaning, and also makes it possible to use logical deduction to infer additional information from the facts stated explicitly in an ontology – an important feature that distinguishes DLs from other modelling languages such as UML"[3].

- ***Metadata:*** Data about data (creator, version, status …). Sometimes data structure is also denoted as metadata. Additional data that enriches the existing data with information that is not relevant for the core information but may provide a context. The discussion about data and metadata mirrors the one about model and metamodel: metadata is data.

- ***Vocabulary***: The concepts used to describe and represent an area of concern. A set of first class constructs within a language. The subjects of information.

- ***Ontology***[4]: A formal model that allows knowledge to be represented for a specific domain. An ontology describes the types of things that exist (classes), the relationships between them (properties) and the logical ways those classes and properties can be used together (axioms).

- ***Urban energy system***: "The combined process of acquiring and using energy to satisfy the demands of a given urban area"[5].

According to Michel Böhms, some of the (meta) concepts/terms previously identified, can be interrelated in a matrix spanning two dimensions (Tables 1 and 2):

- Level of Abstraction (rows)
- Level of Semantics (columns)

The "Level of Abstraction" distinguishes among Language, Structure and Data whilst "Level of Semantics" would tell us something about the kind of things modelled (at each one of these different abstraction levels) including Objects and Representations. This difference between Objects (e.g. semantics) and Representations is quite relevant; both, on BIM and GIS sides. It should be noticed that the language is typically the same over all levels of semantics ('the language does not distinguish what it describes'). Table 1 illustrates a variety of existing technologies used to describe the semantics of objects. . In Table 2, we carry this discussion over the Linked (open) Data (LD) approach associated to the semantic web technology. The Structure is referred to as Ontologies and the Data is specifically denoted as Datasets.

[3] Krötzsch, M., Rudolph, S., & Hitzler, P. (2013). Complexities of Horn Description Logics. In ACM Transactions on Computational Logic 14 (1), 2:1–2:36.

[4] http://www.w3.org/TR/ld-glossary/#ontology

[5] Keirstead, J., Shah, N. (editors) 2013. Urban Energy Systems: An Integrated Approach. Urban energy systems: an integrated approach. London: Routledge.

Table 1. Concepts related to the description of objects using standard data models

Level of Semantics / Level of Abstraction	Objects	Representations ('geometry')
Language (for Structure/Data)	OWL, RDFS, RDF / Turtle, RDF-XML, N3 UML XSD / XML EXPRESS / SPFF ….many	
Structure (meta-data, ontology, schema)	Odysseus dEPC Semanco ontology Dublin Core, QUDT CityGML IFC2x3	GML IFC geometry part OSM schema
Data (models, instances, individuals)	CityGML Berlin-data IFC model Measurement set acc. to dEPC	Open Street Map (OSM)

Table 2. Concepts related to the description of objects using linked data

Level of Semantics / Level of Abstraction	Objects	Representations ('geometry')
LD Language (for Structure/Data)	OWL, RDFS, RDF / Turtle, RDF-XML, N3	
Ontologies	Odysseus dEPC Semanco ontology Dublin Core, QUDT IFC (now as ontology iso scehma) …	GML ontology IFC geometry part OSM ontology …
Datasets (individuals)	Measurement set acc. to dEPC	Open Street Map (OSM) as RDF data now

4.2 Ontology building: methods and tools

In order to design an ontology, it is essential to know its purpose (what the ontology is for). Knowing the purpose enables ontology developers to reuse ontologies (or ontology modules) that already exist. Modelling a domain is a very complex task. It cannot be done from scratch every time. To minimise the work, models need to be built as assemblies of components that are already available.

The ontologies and models presented during the VoCamp have been developed with a variety of tools. Some developers used Protégé (or its web version) to create the ontology in a collaborative manner with domain experts. It was pointed out that some of these tools are difficult to use for non-ontology experts. This was one of the reasons that led to the creation of an ontology editor based on graphical representations in the SEMANCO project. This editor hides the complexity of editing an ontology, but some expressivity is lost in the terms of axioms and constructs used. The resulting ontology file can be loaded in other tools, like Protégé, where users can continue editing the ontology.

An advantage of using Semantic Web technologies (web languages such as OWL, RDFS, RDF, serialisations like Turtle and SPARQL) is that the information modelled with these languages can later be used by reasoning engines to derive sound inferences. Another benefit is the possibility of making the models and datasets part of the Web of data, thus enhancing models and facilitating the sharing, reusing and linking of data.

4.3 Ontologies and their relations with existing standards

An important topic discussed during the VoCamp was the relation between the ontologies created by the research projects with the existing data models, in particular with CityGML and IFC. At this point, there seems to be two approaches: a universal approach which solves "all" application cases – represented by the standard data models –, or a particular approach addressing every application separately – using linked data and ontologies . It was concluded that the generalisation approach (centralised) is not feasible, since it is very difficult – and sometimes not desirable – to reach an agreement between the different user communities to create a common ontology. For example, it took CityGML six years to reach its current status as de facto standard. Moreover, building a generalized solution requires a wide range of domain experts to provide input and to build consensus through some sort of formal decision-making structure. In the individualization approach (distributed), such as the one adopted by the SEMANCO project, ontologies are created based on well-established standards, like ISO or CEN or even the existing data models such us CityGML and IFC. In this case, the ontology building process does not start from scratch but from previously agreed definitions. In this context, the role of ontologies is to create bridges between these models. Specifically, ontology alignment methods can be very helpful to create links between models.

It also needs to be considered that a single standard such as IFC might lead to different versions of RDF Vocabularies or OWL ontologies . The question is who would be in charge of providing and maintaining these ontologies.

In order to avoid reinventing the wheel in every project, it is important to reuse the existing ontologies (or their basic building blocks) as a strategy to foster sharing ontologies. However, there are still difficulties that prevent from ontology sharing: lack of information and lack of procedures to document them. To overcome some of these difficulties the Ready4Smartcities project is creating an eeOntology Catalogue (http://smartcity.linkeddata.es) to document, assess and facilitate access to ontologies to be used in smart cities.

4.4 Technologies for data integration: ontologies vs. data fusion

Semantic web technologies offer a technological solution to integrate distributed data sources from different domains. A prime example is presented by the SEMANCO project. Integrating data using semantic web technologies implies the definition of mappings between the available data sources and the OWL ontology files that stand for domain models corresponding to the data sources. On the one hand, there are not too many tools to support users – domain experts, ontology and non-ontology experts – in the creation of the mappings. On other hand, rewriters – which transform the data sources into RDF – are not performing so well as databases. Open source tools like D2R Server and Ontop are progressing but are far from commercial tools such as Ultrawrap and Virtuoso Server.

Alternatively, data fusion techniques can be used to integrate disparate data sources. This technique has its own problems, particularly with regard to cleansing data, keeping data updated.

Data fusion/analysis and ontologies can complement each other. Ontologies provide labels to the data that can be exploited in data fusion/analysis. The labels provide preconceived and existing information on the data, which might be difficult, if not impossible, to obtain from the data itself. Equally, statistical and mathematical calculations and analyses could be fed back into the ontologies, which could give new results. Data fusion and analysis can exploit the results provided by the application of ontologies and ontologies can be created from the results of the data analysis. Ideally, this interaction between ontologies and data fusion/analysis would occur automatically without human intervention. The labels from ontologies would be employed from existing repositories, then the data fusion/analysis would be executed and the potentially created new ontological elements could be created in the data fusion/analysis process and added to the repository for the visualisation process.

4.5 Smart city: physical models vs. activities

In the projects presented, there were multiple visions of what a smart city is: the layers that compose the city (transport, health, energy supply) and the activities that take place in it were described differently in each project. However, the application of ontologies to smart city modelling relies on the answers provided to these two basic questions: what a city is made of and which activities take place in it.

To create a model of a city (or, by the same token, of a building), it is necessary to consider both its physical components and the processes that take place in them. Ontologies need to be used not just to describe “what is there” (objects and actors) but also to capture “what is happening there”, that is to say, the activities that are taking place (actions and goals). Ontologies could be a suitable technology to model the interactions between socio-technical systems and physical systems. Since the physical system provides constraints for the activities it could help build behavioural models that sit on top of those and interact with, for example, databases with technologies. In this regard, a systemic approach to smart city modelling could be supported by a Social Technical System (STS) ontology, and by City Process Management.

4.6 Multiple scales and levels of details

In an urban context, it is necessary to have different levels of detail (for example CityGML’s LOD1, LOD2) to represent more and less information of an urban model. A change of a scale is not the same as a change in the level of detail (in quantitative terms). Rather, it is a change in the way of thinking about an object (a building, neighbourhood, city or region). The problem with having different models with multiple levels of detail is to integrate all of them in a unified, single model. The segregation of the models with different level of detail makes it difficult, for example, the aggregation of data across the different scales.

A seamless connection across scales would enable the aggregation of indicators from lower scales onto upper ones and conversely (scaling up and down). Ontologies can help to support this process of integrating data across different levels of detail. This requires ontologies that can be flexible enough to handle multiple aggregation and disaggregation of data across the different levels of detail.

4.7 Resources

A list of available resources mentioned by the VoCamp participants, which can be useful for researchers working with ontology modelling is summarised in Table 3.

Table 3. Resources for ontology modelling

Name	Description	Related Project
eeOntology Catalogue (http://smartcity.linkeddata.es)	An on-line catalogue of ontologies related to the smart city domains such as energy, smart devices, building, among others.	Ready4SmartCities
WikiSensing (http://wikisensing.org)	A sensor data management platform to store sensor data based on ontologies	Digital City Exchange
Enipedia **(**http://enipedia.tudelft.nl/)	A semantic wiki containing linked data about energy and industry systems as well as tools (e.g. for queries).	Odysseus
OntOlogy Pitfall Scanner (http://www.oeg-upm.net/oops)	OOPS tool to detect some of the most common pitfalls appearing when developing ontologies.	Ready4SmartCities
QMiner (https://github.com/qminer/qminer)	Analytic platform for real-time, large-scale streams containing structured and unstructured data.	NRG4Cast
Odysseus Web Protégé (http://vcon1.tno.nl:8080/webprotege /#List:coll=Home;)	Web Protégé server which contains the ontologies developed in the Odysseus project.	Odysseus
CMO (http://www.modelservers.org/public/ documents/cmo.pptx)	An upper ontology adding decompositions, quantities and units to OWL2 for reuse in other ontologies like in Odysseus dEPC Ontology.	Odysseus
Alignment API (https://gforge.inria.fr/frs/?group_id= 117)	The Alignment API enables various ontology matchers to share the same format and interface for accessing matching results. It also features a reference implementation and the Alignment server.	Ready4SmartCities

5 PRESENTATIONS

5.1 Day 1

5.1.1 Session 09:00 – 10:00: Introduction

Leandro Madrazo, Project Coordinator of the SEMANCO project and responsible for the organization of the VoCamp, welcomed the participants and presented the program agenda.

The three proposed topics – Urban Energy Systems, Data Sources and Visualisation – were grouped in two sessions.

SESSION 1. Modelling Urban Energy Systems

- Accessing data to create urban energy systems models: inputs and outputs, interactions, determining scales and boundaries
- Multiple representations of the system dynamics: evolution over time, projections, updating data
- Application of information models to represent 3D objects (CityGML standard, and other)

SESSION 2. Integrating Multiple Data Sources

- Creating models of urban energy systems using ontologies (ontology matching)
- Integrating multiple data sources from different energy related domains
- Application of information models to represent 3D objects (CityGML standard, and other)

Introduction to the VoCamp series

Leandro then provided the floor to Dimosthenis Ioannidis, who introduced to the participants the overall concept, objectives and organisation procedures of a Vocabulary Camp. The purpose of these VoCamps can be summarised as follows:

- To present, discuss and propose a shared vocabulary that can be used for the development energy efficiency projects
- To analyze existing ontologies and concepts used by different stakeholders
- To propose recommendations for the alignment of respective standardization bodies

During his presentation, Mr. Ioannidis gave an overview of the previous VoCamps and announced the next ones which are taking place in April and July respectively. The will be organised under the auspices of the research project Ready4SmartCities (R4SC) which is taking over the role of organisation the events from Adapt4EE.

		Task Name	Start	Finish
1		1st Vocamp	Thu 15/11/12	Fri 16/11/12
2		*Energy Efficiency Modeling*	Thu 15/11/12	Fri 16/11/12
3		*Organizer: CERTH/ITI, Thessaloniki, Greece*	Thu 15/11/12	Fri 16/11/12
4		*Champion: Dr. Dimitrios Tzovaras*	Thu 15/11/12	Fri 16/11/12
5		2nd Vocamp	Thu 14/2/13	Fri 15/2/13
6		*Building Information Models (BIM)*	Thu 14/2/13	Fri 15/2/13
7		*Organizer: UNAV, Pamplona, Spain*	Thu 14/2/13	Fri 15/2/13
8		*Champion: To be defined, Ont.Engineering Group, Madrid*	Thu 14/2/13	Fri 15/2/13
9		3rd Vocamp	Thu 13/6/13	Fri 14/6/13
10		*EupP (Energy using and producing Products) Management*	Thu 13/6/13	Fri 14/6/13
11		*Organizer: Technical Univ. of Wien, Vienna, Austria*	Thu 13/6/13	Fri 14/6/13
12		*Champion: Prof. Christophe Grimm*	Thu 13/6/13	Fri 14/6/13

Figure 1. Planning of the VoCamps series

Presentation of the 4th VoCamp: objectives and structure

The structure of the proposed program for this VoCamp was based on the intertwining of three different domains which become interrelated in the process of creating and applying ontologies in the field of urban planning, as described in the following figure.

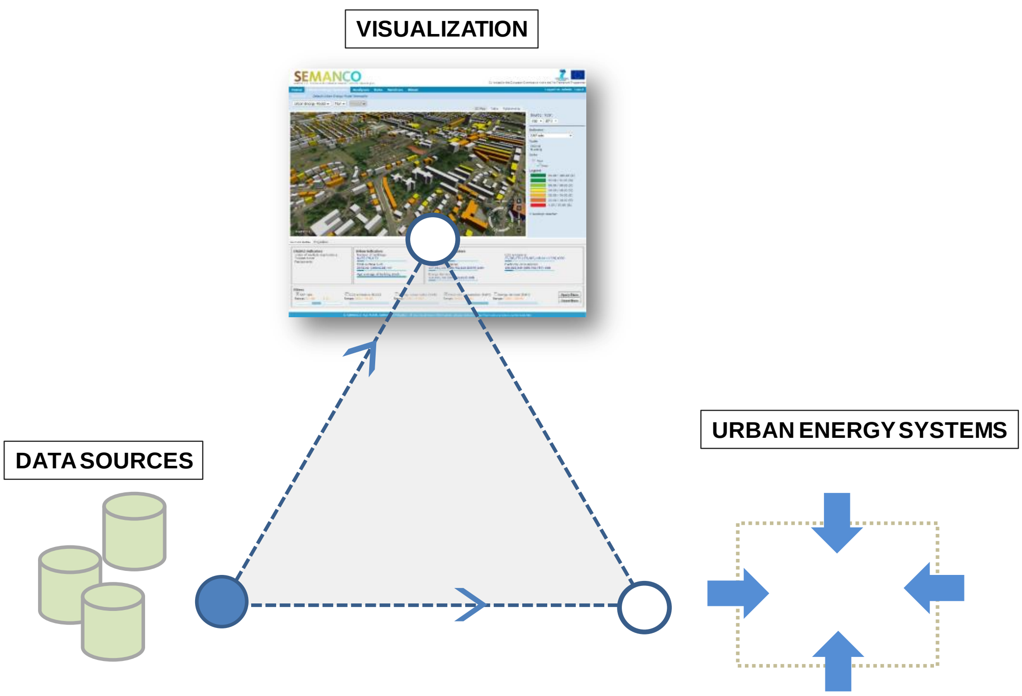

Figure 2. Structure of the 4th VoCamp

After the presentation delivered by the ADAPT4EE project representative, Leandro introduced the theme of the 4th VoCamp and proposed a discussion framework based on the following assumptions:

- The scope of the VoCamp is the application of ontologies to integrate multiple domains and scales in order to develop models of urban energy systems, which help different actors – urban planners, consultants, policy makers, and dwellers – to make better-informed decisions to reduce energy consumption and carbon emissions in urban environments.

- The construction of a shared vocabulary can be understood as a process by which the knowledge from the various experts participating in the definition and solution of a problem is formalized by means of the ontologies.

- An urban energy system encompasses multiple scales that become intertwined because of the system's activity. The relationships of system's elements across scales can be formalised by means of ontologies.

- The problem of carbon emission reduction in urban areas cannot be constrained to a particular geographical area or scale, nor is it the concern of a particular discipline or expert: it is a systemic problem that involves multiple scales and domains and the collaboration of experts from various fields.

After explaining the previous statements, Leandro proposed the following topics for the subsequent discussion in the working sessions:

- **Energy efficiency, reduction of carbon emissions are systemic problems; a systems approach seems to be suitable to the problem.**
- **An energy system is an elusive concept: there are difficulties to set its boundaries, to figure out its dynamics, to define its goals.**
- **Models of energy systems enable to grasp part of an energy systems complexity.**
- **A model created with ontologies is not just a representation of the observed reality, but also a formalization of the knowledge that experts from different domains have about a complex problem related to energy efficiency; it is not a model of reality, but a model of how we think about a particular reality (a metamodel, a cognitive model).**
- **In order to share vocabularies, it is necessary to agree on the fundamental approaches that support the creation of ontologies in the domain of urban energy (systems approach).**

Presentation of the SEMANCO project

The next presentation by Leandro was a summary of the work done in the SEMANCO project to apply ontologies to planning of energy efficient urban areas. Leandro pinpointed the importance of using semantic technologies to model a problem with the participation of domain experts and ontology engineers. With this purpose, in SEMANCO, the construction of the ontologies started by describing a problem as a use case, using templates developed in the project. A use case encapsulates data, tools and users in a particular context. This ensemble of data, tools and users – formalized by means of ontologies – makes an Urban Energy Model. An Urban Energy Model stands for the knowledge a group of experts have about a complex problem concerning energy efficiency and carbon emission reduction in urban environments. Users can later operate with these model with the interfaces provided in the SEMANCO integrated platform.

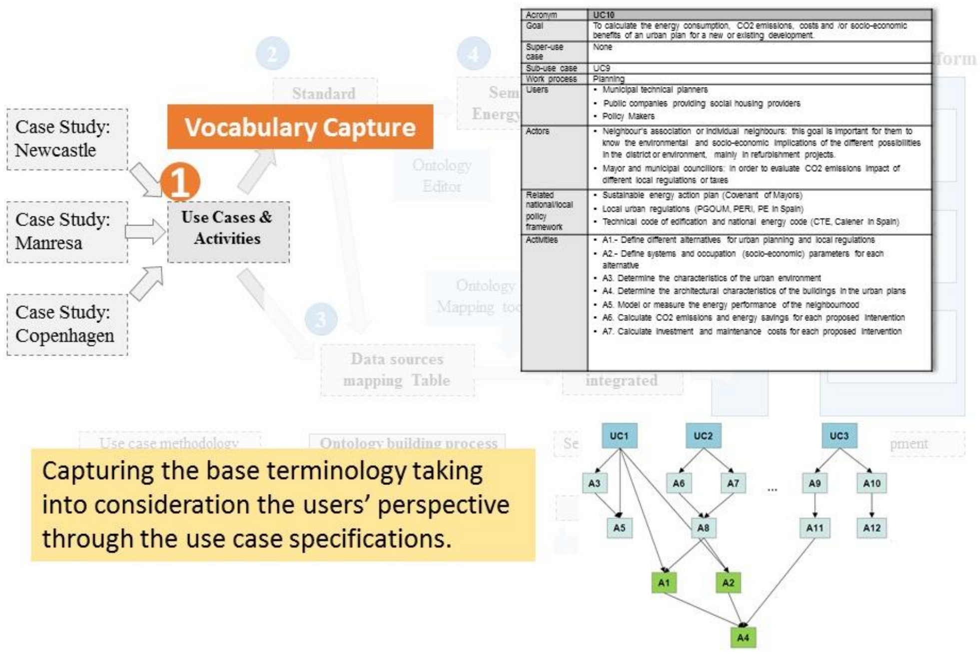

Figure 3. Defining an urban energy problem as a use case

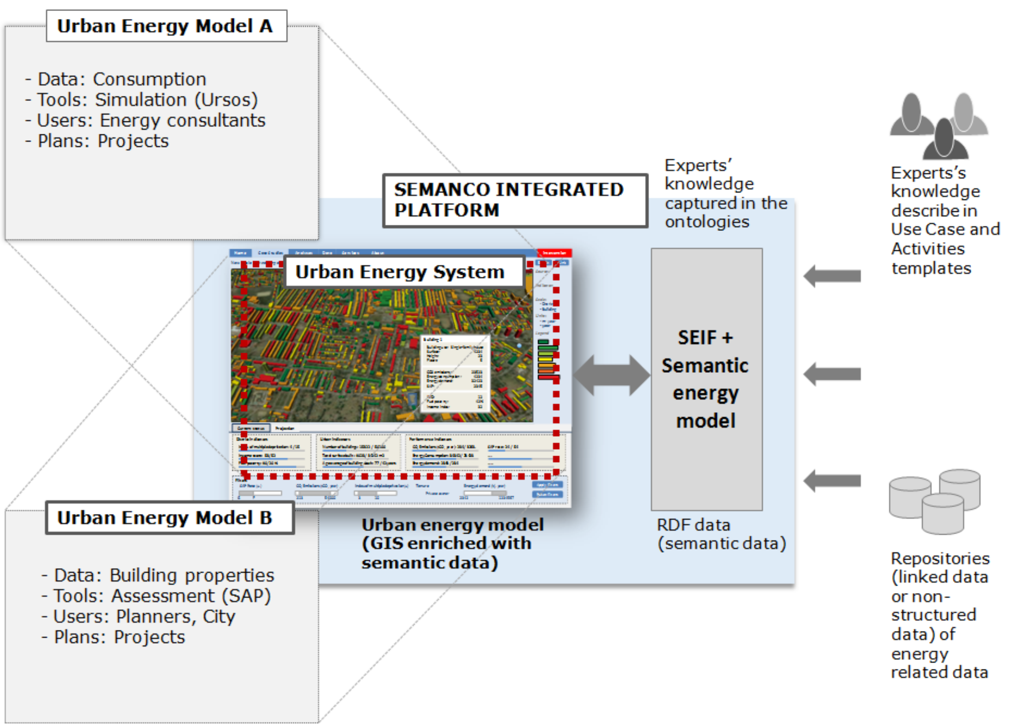

Figure 4. Process to integrate the semantic data in the SEMANCO platform

A discussion followed the presentation.

One of the topics of discussion was about the methodology to model knowledge construction process using ontologies. Most participants agree that domain experts need to express their knowledge in informal ways (e.g. as in the use cases templates used in SEMANCO) which would be the starting point for creating semantically enriched models. Thomas Liebich remarked that a similar methodology has been proposed by IFC through the Information Delivery Manual.

German Nemirovski asked if the statement that an "ontology is not a model of reality, but a model of how we think about a particular reality" could imply that an ontology is a metamodel. Following this discussion Gonzalo Gamboa pointed out that "there are cannot be right models, but only useful models". Asunción Gómez Pérez contended that there could not be a unique ontology for everything since every project/context can have their own ontologies. The key point is to connect them through ontology alignment theory.

5.1.2 Session 10:00 – 10:45: Keynote "Using ontologies to store, share and apply city data in simulation models", Koen van Dam

Koen van Dam, from the Imperial College in London, gave an overview of the next generation tools and infrastructures that will enable cities to become smarter, meaning that that they can offer new enhanced services to its citizens. During his presentation, he outlined several ongoing approaches in respect to smart cities. A smart city is not limited to install intelligent objects in the city ("smart city" vs. "a city where smart things happen"). Rather, it is about integration of multiple sectors (energy, transport, tourism) by collecting, combining, analysing data to help people plan, manage and invest. This requires a two-way approach integrating physical systems (infrastructures, buildings, appliances) with the activities carried out by agents operating on those physical systems. In the works done by the research group at the Imperial College, a sociotechnical perspective is adopted which combines actors as well as physical systems. From this interaction, it emerges a systems behaviour as described in the following diagram (Figure 5).

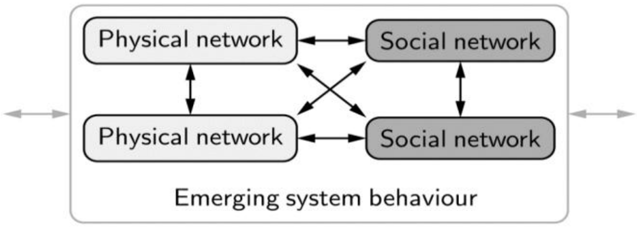

Figure 5. Emerging system from the interaction between physical and social systems

Koen emphasised the role of ontologies as a shared language across decision makers and other stakeholders from multiple domains. Ontologies to model these socio-technical systems are needed. This requires a shared language to bring together "elements" in the model, model builders and decision makers across different domains. As an example of this approach, Koen presented parts the Social Technical Systems (STS) ontology, a generic vocabulary that can be used in energy and industrial networks.

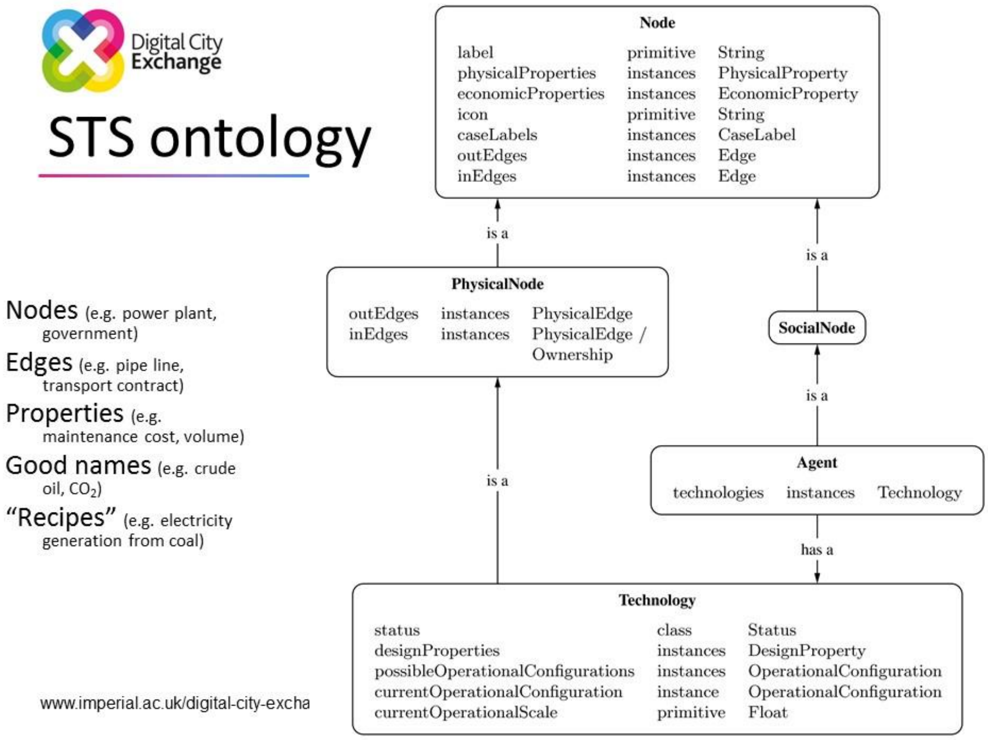

Figure 6. STS ontology that could be used to model the interaction between building blocks in a city (including socio-economic aspects)

During this session, Koen also presented some of the approaches currently followed for the development of a systematic approach to the design and operation of urban energy systems. In particular, he explained how concepts (classes) and underlying data models can be used for interchange of data in various domains. Moreover, he outlined the importance of aligning concepts across different vocabularies and provided an example of building a model combining concepts described in two different ontologies, namely UES and STS, as illustrated in the figure below.

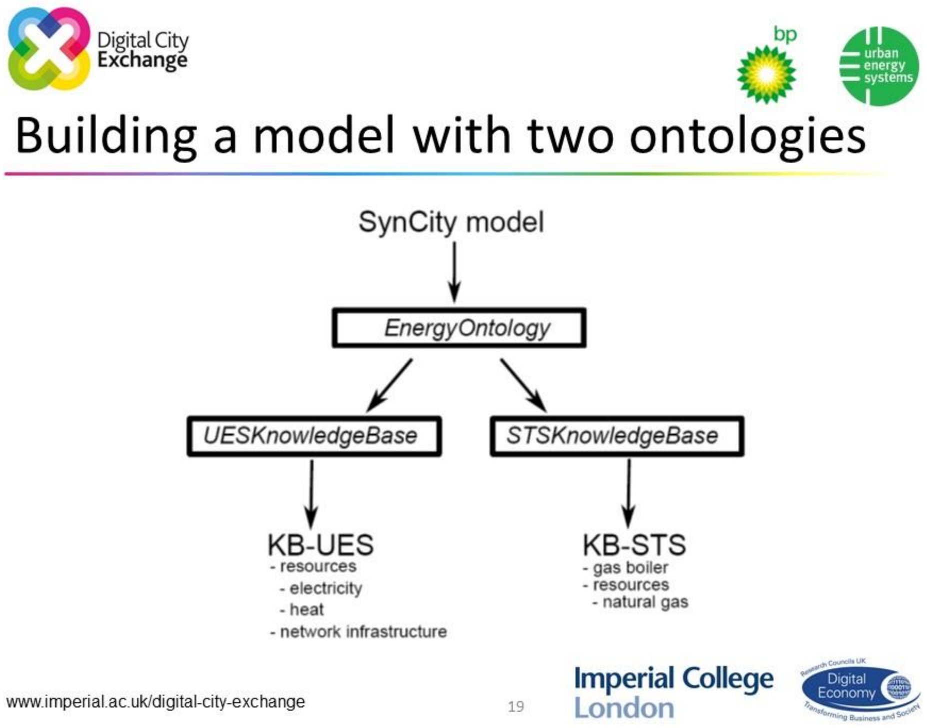

Figure 7. Combining ontologies for deriving new knowledge across domains

Finally, Koen referred to the work done in the Digital City Exchange (DCE) project aimed at integrating data in different domains (transport, energy, water, waste) at a city scale. He showed several case studies for utilising such models for predicting (or simulating) the optimal charging of electric vehicles (EVs) in the underlying smart-grid. Within this project, a platform to handle models, connect them, and publish them has been created. In addition, he explained how different standardised data models used in the smart city domain (a report of British Standards Institution group -BSI- will be available soon) are being mapped to each other. DCE took data from sensors to analyse them, creating a multi-integrative layer. For this purpose, DCE uses WikiSensing (http://wikisensing.org/), a sensor data management platform to store sensor data, which is based on ontologies. The workflow engine allows executing different models with the data. The applications to build new services sit on top of the model.

After Koen's presentation, there was a discussion about the decision-making processes concerning energy management in city (centralised or not) as well as on the credibility of the predicted models used in the EV scenarios. He pinpointed that best practices are needed to expand the application of smart cities technologies. For this reason, it is important to publish the available standards, as the City Protocol is encouraging. There are many standards that define how systems talk to other systems. Further information will be made available in the "Report on mapping smart city standards" by BSI (www.bsigroup.com). Some participants asked about the accessibility to the ontologies developed in the projects presented. According to Koen, making these ontologies available is not always so easy, since not everybody is willing to share his or her work. To overcome this, people should be convinced of the benefits they obtain by providing data.

5.1.3 Session 11:30 – 12:15: Keynote "Urban information modelling", Claus Nagel

Claus Nagel is Head of Software Development at the company virtualcitySYSTEMS GmbH in Berlin, and Vice Chair of OGC Standard CityGML. He gave an overview of the CityGML standard and the available information views that is available for end-users (consumers of actual digital representations of CityGML instances). The standard currently supports different application domains, ranging from urban planning to navigation and disaster management.

The distinctive approach of a CityGML model is that it describes the physical reality of the city, that is, the objects that make the built environment and their properties. Furthermore, there is another distinction to be made between a CityGML model and a purely "graphic" 3D model (Google Earth, KML/Collada, 3DS): the first include semantics and the second ones only geometric information. Since a CityGML model embodies the "semantics", it is possible to query about its components: What is it? What is it for? With which elements is related to?

Semantic models such as those provided by CityGML are a key to Urban Information Modelling. Their creation requires a consensus about the meanings of the objects, that is to say, an ontology. However, a consensus is needed to define these ontologies. Applications can rely on the data quality of the semantic models. Providers of 3D city models (for example, municipalities) in CityGML format can be sure that the model will be useful for a wide range of applications.

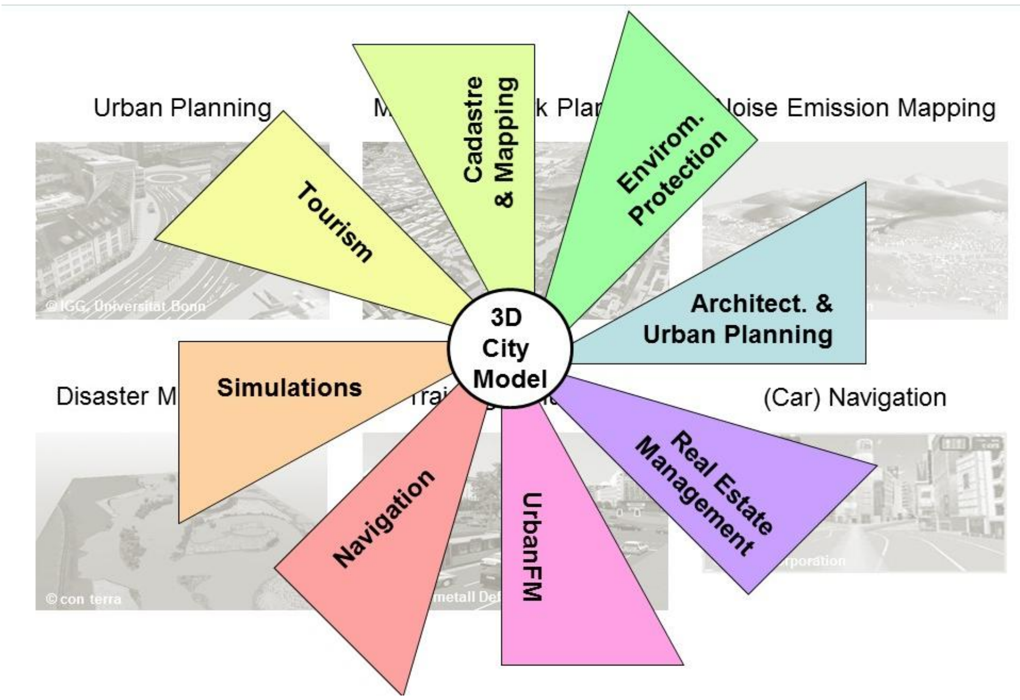

Figure 8. Application domains of the CityGML standard

CityGML comprises different thematic areas such as buildings, vegetation, water, terrain, traffic, among others. It provides an ontology of the urban space based on the classification of well-defined urban entities with spatial and non-spatial properties and relationships. It is ISO compliant conceptual UML data model and GML-based exchange format. It is also an international OGC standard since August 2008. Claus introduced the hierarchical vocabulary used in the CityGML standard along with the different scales (i.e. levels of details) which the standard supports. It was pointed out that the level of detail supported at the building level is not the same that the one that is currently supported by the BIM standards (e.g. IFC or gbXML). The Level of Detail (LOD) in a CityGML model not only has an impact on the representation but it also affects the semantics of the model. Claus argued that the difference between an IFC-based model and a CityGML model could be established in terms of level of detail: a BIM/IFC could be assimilated to a CityGML model with LOD5, for example.

Mechanisms to connect IFC and CityGML standards are currently missing. The question is how easy is to connect them with external reference mechanisms. An example is GEOBIM, developed by TNO within the OPENBIM server initiative. Ontologies could also be a mechanism to connect them. Then, if CityGML and IFC models are formalised using semantic ontologies, inference reasoning and data linking procedures could be applied to both.

One relevant example of an application of CityGML models in the field of urban energy is the Energy Atlas Berlin which has been used, among other purposes, to determine the solar potential of the roofs and to create noise pollution maps. Similar models have been created in many German cities with the same intention. The idea behind the Energy Atlas Berlin is to put energy data in a CityGML model to create a decision support system with the goal of analysing the city’s energy performance. Other projects in this line are being developed in Europe. In the Detorba project, ANSYS is connecting CityGML models to their simulation platform. Santiago de Compostela, in Spain, has a CityGML model created by Tecnalia. In all of these examples, the graphical representation of energy outputs is a common issue.

There were discussions on the extension capabilities of the CityGML standard through the application of domain extension mechanisms such as the Energy ADE. CityGML Inspire ADE will be implemented and will be mandatory by the European Commission. Moreover, there was a discussion on how the concepts used in the CityGML data scheme could be semantically aligned with the ontology created in the SEMANCO project. CityGML has a semantic and geometry hierarchy, which enables to visualize models in web browsers using, for example, Agency9’s technology. This could be another point of contact with SEMANCO.

It was pointed out that a research objective could be the conversion of the CityGML to a hierarchical ontology that will enable reasoning capabilities to the respective stakeholders (decision makers, analysts, architects, among others). This would contribute to unifying two currently disjointed worlds, represented by BIM and CityGML. TNO representative, Michel Böhms, outlined the ongoing efforts on the delivery of GeoBIM ADE. Other initiatives, such as Open BIM’s attempt to link CityGML with IFC, were discussed as well.

5.1.4 Session 1 - 14:00 – 15:30: Modelling urban energy systems

In this session, ongoing efforts and the semantic-enabled models that have been developed (or being developed) in ongoing European Funded projects were presented.

Leandro Madrazo, from La Salle Engineering and Architecture School, Barcelona, Spain, presented the approach adopted in the SEMANCO project in which ontologies have been used to assure the interoperability between different data models and to facilitate their interaction with multiple applications (building energy assessment, simulation). This approach is summarised in the following diagram.

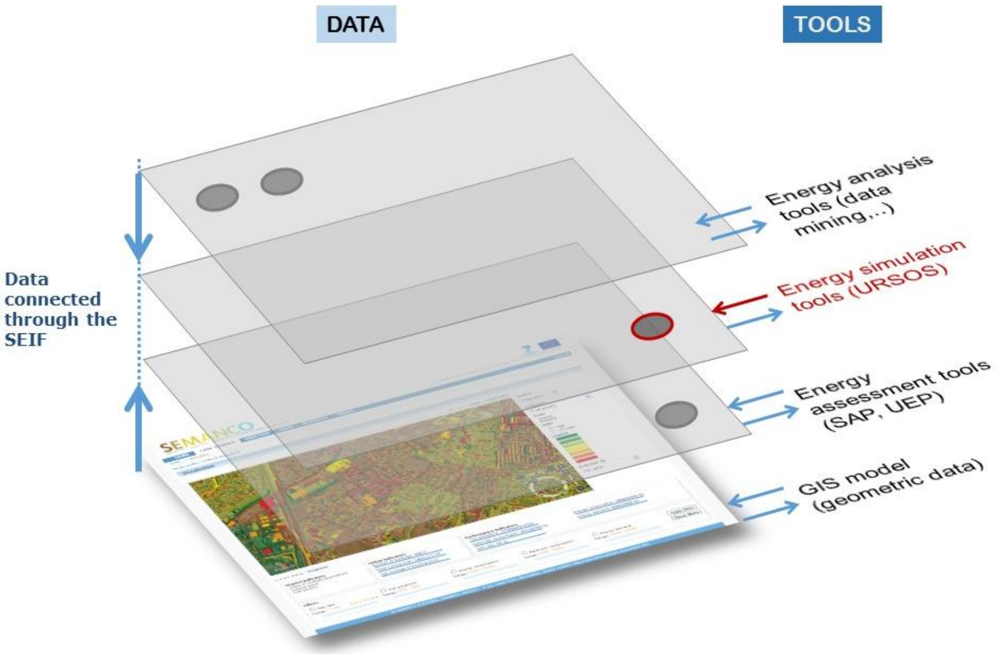

Figure 9. Interoperability between data and tools through the SEIF (Semantic Energy Information Framework) developed in SEMANCO

The technical description of this approach can be found in deliverable D4.5 *Report on Semantic Energy Information Framework*[6].

María Poveda, from the Ontology Engineering Group of the Universidad Politécnica de Madrid, Spain, presented the project of the Ontology Catalogue that will be developed within the Ready4SmartCities project. In addition to the methodology to create the repository, there was a discussion by the participants regarding the need of such publicly available catalogue. It was pointed out that existing repositories are either constrained to one domain and/or too detailed. The proposed methodological framework for collecting ontologies in the energy domain will enable the evaluation and comparison among existing ontologies used in different scales (from city to district, and from neighbourhood to building). The Ontology Catalogue will be a place to find models in different formats (RDF, OWL, UML, SKOS) to assess ontologies based on some quality indicators.

[6] http://semanco-project.eu/index_htm_files/SEMANCO_D4.5_20131018.pdf

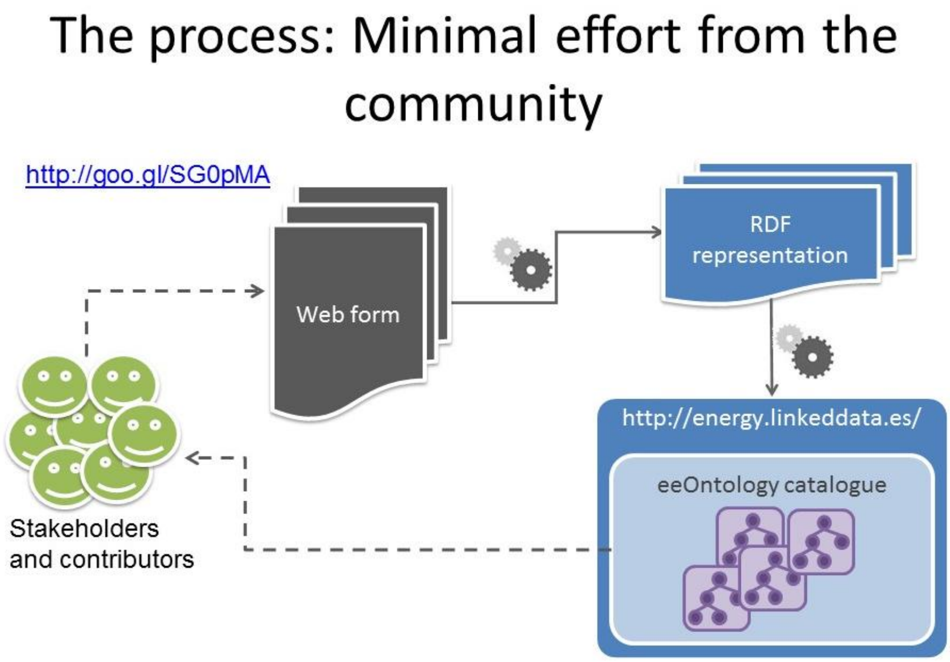

Figure 10. Towards the delivery of a eeSemantics catalogue for smart cities

Vincenzo Corrado from Politecnico di Torino, Italy, introduced the vocabulary used to create the SEMANCO ontology. As Vincenzo pointed out, even though there are energy many energy standards at the building level there are no well-established standards at the urban level. He described the methodology followed in SEMANCO to create first an informal vocabulary from the use cases and to transform it later in a formal vocabulary which would be afterwards, modelled as an ontology.

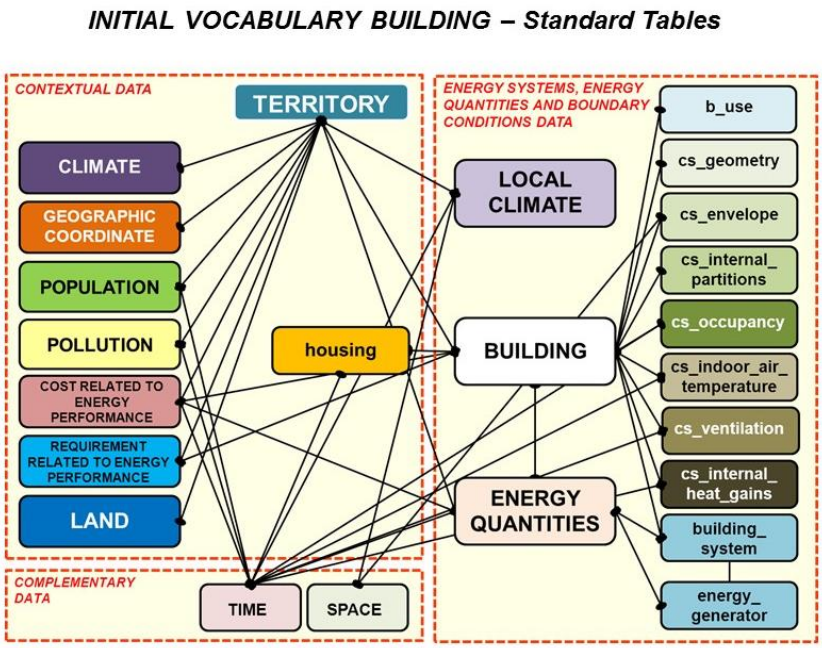

Figure 11. A portion of the generation process of the vocabulary

Gonzalo Gamboa, from CIMNE, Spain, referred to the limitations inherent to the use of fixed hierarchical systems to classify land uses, particularly in urban energy systems that are essentially dynamic. It was discussed whether there should be a semantic mechanism to aggregate information across different levels (e.g. aggregating from building to neighbourhood, to district and city levels). He argued that ontologies should be flexible enough to handle multiple and flexible aggregation structures.

In the following discussion, Leandro stated that a change of scale should not be understood in terms of increasing or decreasing the amount of information in a model. Rather, a change in scale implies a change in the way of thinking about a problem.

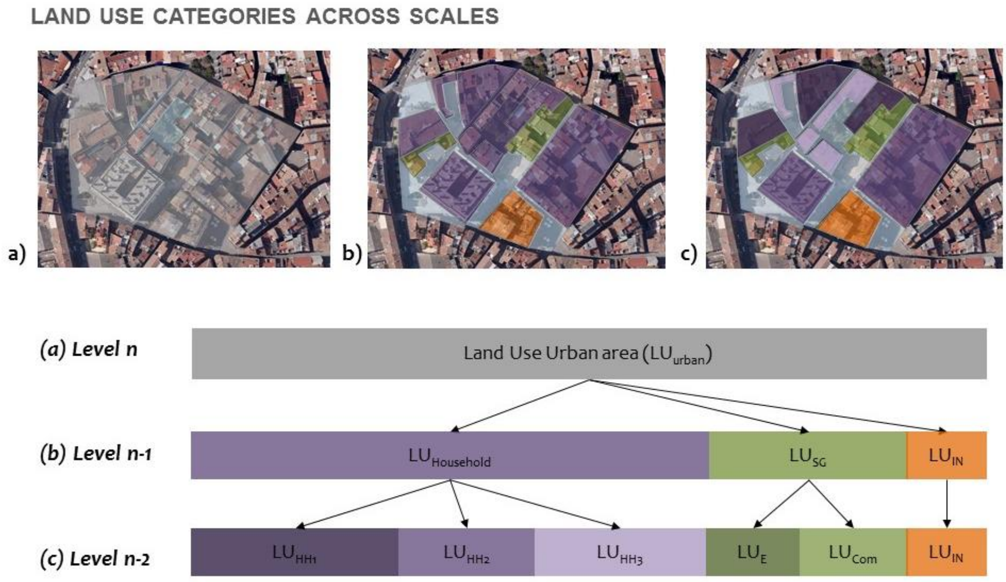

Figure 12. Land uses for aggregating information in an urban domain

Maja Skrjanc, from Josef Stefan Institute, Slovenia, presented the work of the NRG4Cast project. This project deals with data collection and modelling and visualization of information from events that occur at the city scale. She presented the QMiner analytic platform, in which energy consumption and the social media can be related.

Conclusions of the session

- The role of ontologies in the domain of urban planning, as a means of communicating and sharing knowledge among decision makers, shall be clarified further.
- There is a potential need for high-level abstractions (at the data and processes level) to find optimal semantically-enriched solutions for the use and exploitation of urban data.
- It is necessary to develop platforms and models, which exploit the potential of ontologies to integrate data and domains.
- It could be interesting to have “models” that translate models from one scale into another.
- Data monitoring is a task done with a specific purpose. This purpose influences the way the data is formalized. In addition, data acquisition is never neutral; data is always gathered with an intention.

- It is important to reuse ontologies (or ontology modules) that already exist. Modelling a domain is a very complex work that it should not be done from scratch every time. Rather, it should the result of assembling the knowledge blocks that already exist.

5.1.5 Session 2 - 16:00 – 17:30: Integration of multiple data sources (Part 1)

The facilitator of the session, German Nemirovski, gave the floor to Markus Look, from RWTH Aachen University, Germany, who presented the concepts and the vocabulary used for the delivery of a Neighbourhood Information Model. An automatic process to build a metamodel of the whole city from its components data models was presented.

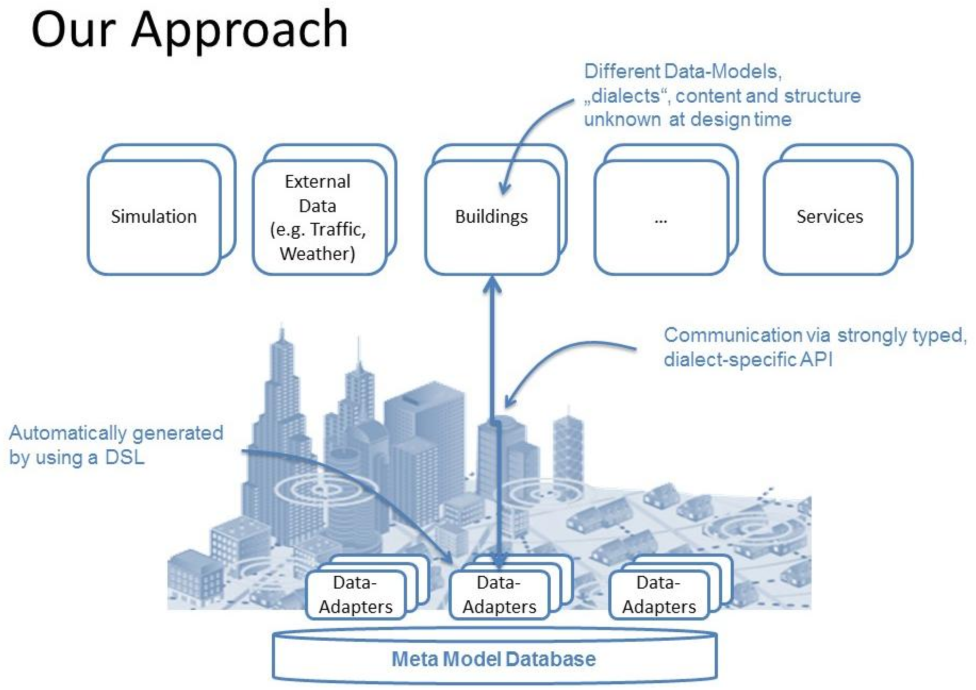

Figure 13. Mapping data models to a meta model

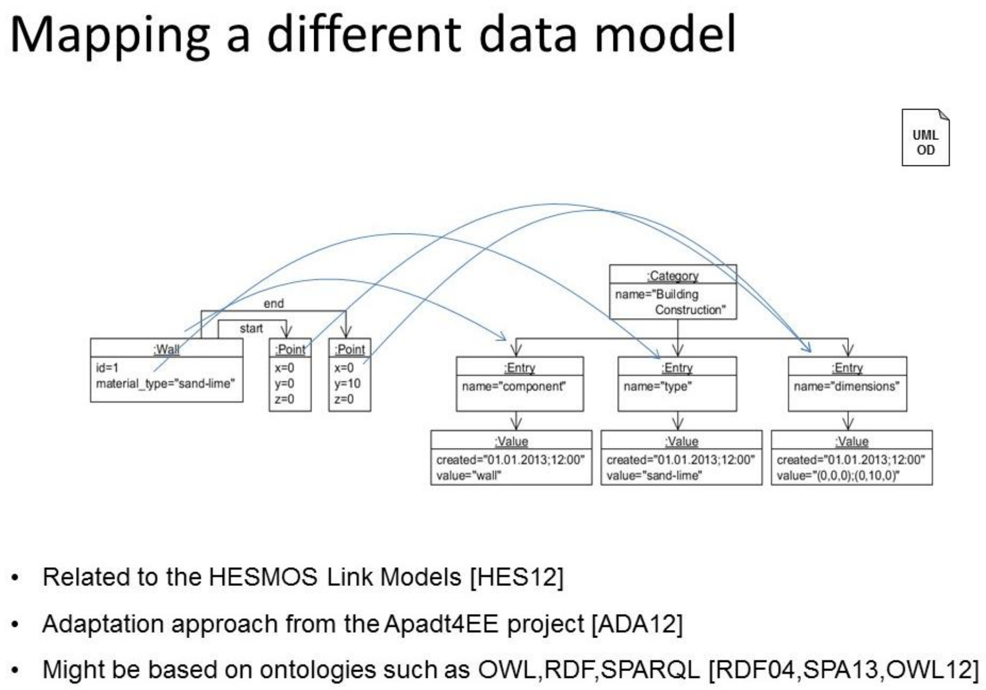

Figure 14. Mapping procedure followed in the Cooperate project

A discussion followed the presentation of the underlying metamodel (hierarchies used, symbolic links) and the constraints that supports. The methodology for uploading the models at runtime was presented along with the application models that have been used provided by the HESMOS and Adapt4EE projects. In addition, the SEMANCO ontology has been expanded to include more elements at the neighbourhood level.

The floor was given to Michel Böhms, from TNO, The Netherlands, who introduced the concepts used in Odysseus project with respect to the energy consumption reduction in buildings via better decision support on BEMs. He pointed out the role of the dynamic Energy Profile Card (dEPC) and its instantiation through a detailed vocabulary in CMO as well as an extension to the CityGML Energy ADE. He used an example a room description in the SUMO ontology to point out that the upper nodes are irrelevant to building experts.

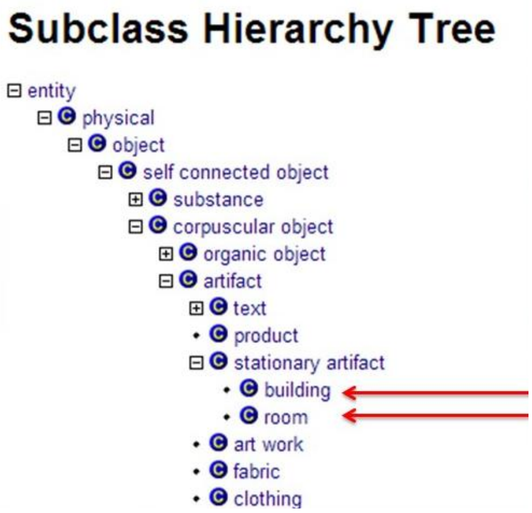

Figure 15. A description of a room based on the SUMO ontology

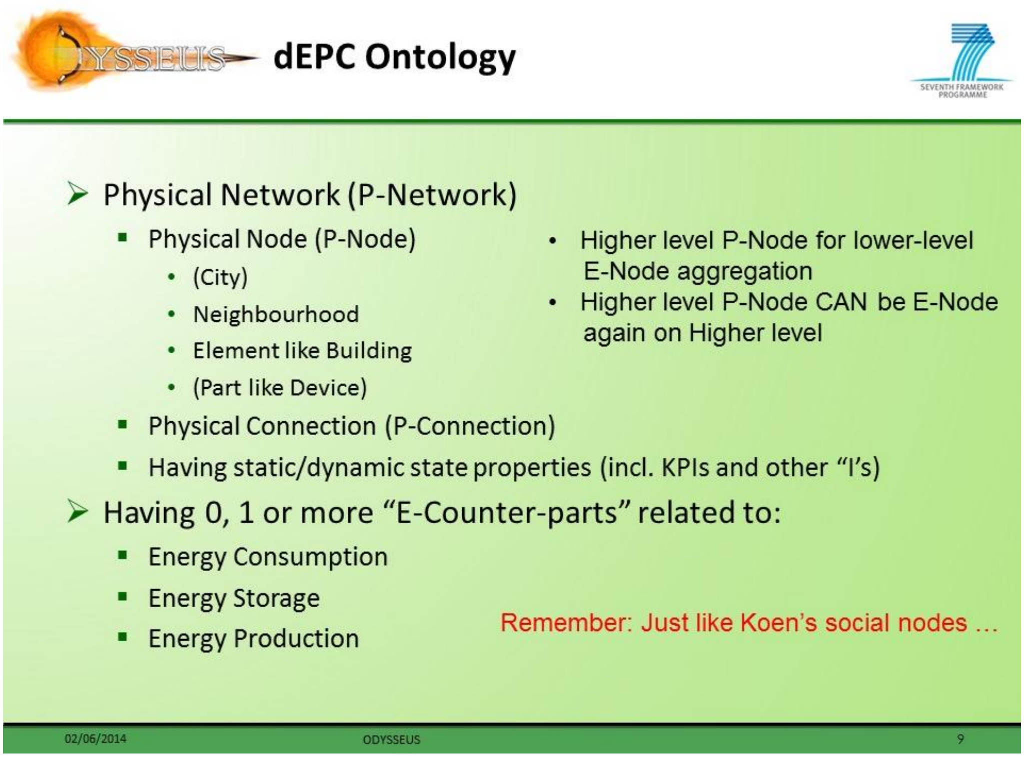

Figure 16. Snapshot of the dEPC Ontology[7] *introduced in Odysseus Project*

There was a discussion on how to enhance the ontology with concepts related also to the flexibility of the buildings that can be used for demand side management or other similar decision making functionalities, for example, trading of energy with ESCOs and aggregators. Moreover, UPM representatives recalled the need to make an optimal use of the tools for knowledge representation by assuring that ontologies "inherit" classes and concepts from existing standardised schemas/vocabularies/ontologies. Leandro pointed that the standards data models such as IFC and CityGML have mechanisms to extend their models. However, such extensions are based on a centralised view where the standard data model is at the centre. Instead, ontologies could facilitate creating bridges between multiple data models, each one based on a different standard. Accordingly, the role of the ontologies is to build bridges between different models. Raúl García Castro contended that an ontology can be a consensus mechanism. Leandro remarked that there might be different roles for ontologies: one is to define terms; other is to define roles and actions. A discussion arose about meaning and semantics: whether the meaning is given by the language or if it is the user (machine or human) of a language who endows this with meanings.

The following presentation delivered by Tomi Räty, from VTT, Finland, focused on the challenges of data analysis in real-time and the need to define the necessary structures for analysis and visualisation of the information. His approach to integrate data is not based on ontologies but on data fusion (e.g. consolidation of the acquired data from disparate sources). Fused data is therefore, automatically analysed using mathematical methods.

[7] The latest version of the ontology is available at http://vcon1.tno.nl:8080/webprotege/

- **Four existing prototypes created by VTT**
  - 1st prototype: LDMS (Logical Decision Making Server) (2006-2008)
    - Rule-based system
  - 2nd prototype: RCA (Root Cause Analyzer) (2008-2010)
    - Automated creation of rules
  - 3rd prototype: NIDS (Network Intrusion Detection System) (2008-2010)
    - Based on augmented RCA technology, applied in a different scenario (network intrusion detection)
  - 4th prototype: RTA (Remote Tester/Analyzer) (under development) (2010-)
    - Current version (4.0) under development:
      - Utilizes triple engine of 1) statistics (Bayesian data analysis,) 2) state machine (Kalman filter,) and 3) artificial neural networks

Figure 17. Existing prototypes for data analysis and visualisation presented by VTT

Finally, Jérôme Euzenat, from INRIA, France, provided an overview of an ontology alignment tool and its scope towards finding similarities among different vocabularies. There were discussions on how to perform disambiguation (e.g. use of CIDER tool) as well as on the purpose of such tools for analysing and reusing core concepts used in a domain ontology. He stated that ontology alignments are links between ontologies, which do not need to modify the ontologies even to reach consensus. He gave some examples of alignment among ontologies.

Conclusions of the session

- It is necessary a consensus on concepts and terms used in urban planning (contextualised either as ontologies, data models or meta models across different scales)
- The common parts shall be identified as it has been done before with standards for semantically-enabled sensors, for example.
- Different approaches for interlinking data have been presented. However, in all cases the tools shall cope with flexible and fixed boundaries depending on the application domains.
- Data analysis and exploration across different scales (including availability of information with different levels of detail) is a hot topic that shall be discussed further by experts in the smart cities domain.
- The relationship between actual data and actions upon them (actionable knowledge) shall be further intensified by the introduction of new tools that support such functionalities.

5.2 Day 2

5.2.1 Working Session - 09:00 – 10:30

The session initially focused on the ontology developed in the SEMANCO project. German Nemirovski, from the Hochschule Albstadt-Sigmaringen, Germany, presented the SEMANCO ontology from a technical point of view. The tools developed within the project to create the ontology – ontology editor and ontology mapping tools – were presented. These tools support users in the ontology development process.

German Nemirovski and Álvaro Sicilia explained how the ontology was built, starting from an informal vocabulary compiled in Standard Tables (Excel file) and then formalized in the SEMANCO's ontology editor. As an example, the structuring of the territory was shown together with the different land classifications (e.g. by use, by economic function, by ownership constrains, by site development).

10	Country						-	a territory of a nation or state
11	has	Region					-	an administrative division of a country
12		has	Climate				-	climate that defines areas of size up to 200 km linear extension
13		has	Municipality				-	a political unit, such as a city, town, or village, incorporated for local self-government
14			has	Local_Climate			-	climate that defines areas of size up to 10 km linear extension
15			has	Neighbourhood			-	a geographically localised community within a larger city, town or suburb
16				has	Land		-	a topographically or functionally distinct tract
17					has	Building	-	construction as a whole, including its envelope and all technical building systems, for which energy is used to condition the indoor climate, to provide domestic hot water and illumination and other services related to the use of the building

Figure 18. Territory structure

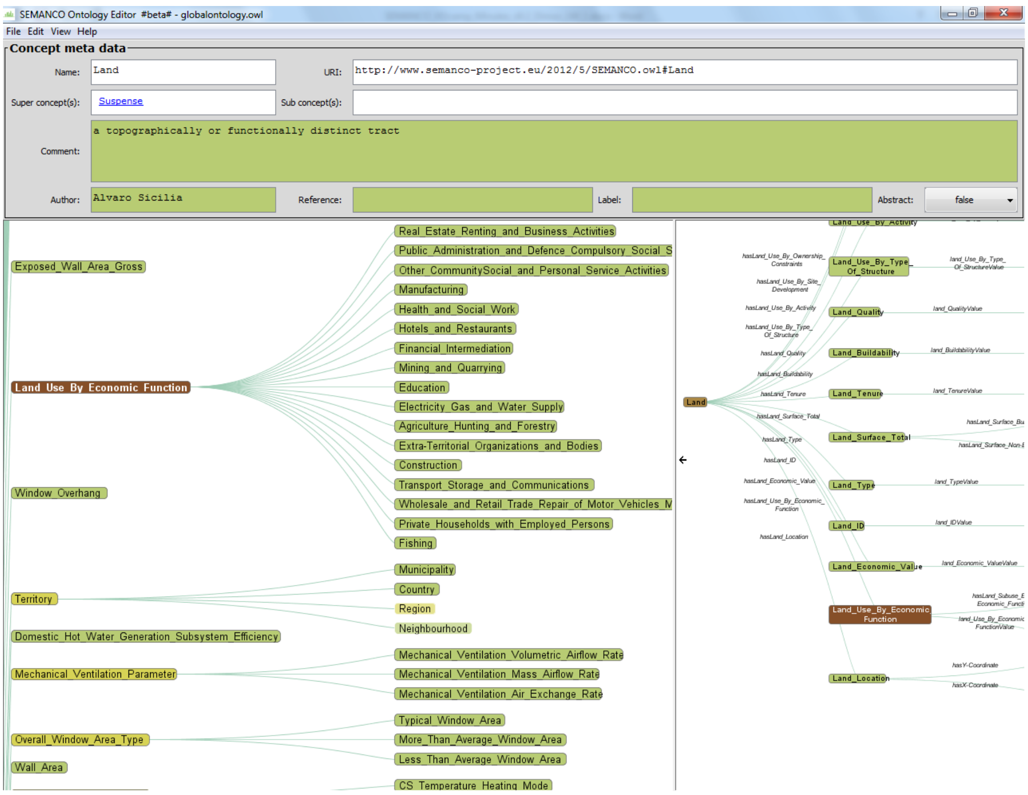

Figure 19. Ontology editor

These two concepts (territory hierarchy and land classifications) are related to the discussions brought about by Gonzalo Gamboa's presentation about fund flow models and aggregation of scales. The theory presented by Gonzalo is not easy to formalize in models. For instance, a CityGML model does not consider the possibility to aggregate data to make analysis at different scales. The SEMANCO ontology has not yet completely implemented the potential of the fund flow model.

Álvaro presented a detailed overview of the ontology building process followed in SEMANCO, from data sources to storage in a layer supporting reasoning capabilities through ontology. Álvaro and German also presented the ontology editor environment developed in SEMANCO to facilitate the collaboration between domain experts and ontology engineers in the ontology design process, and the ontology mapping tools which help users –domain experts, data owners and ontology engineers– to integrate data sources into the semantic energy information framework (SEIF).

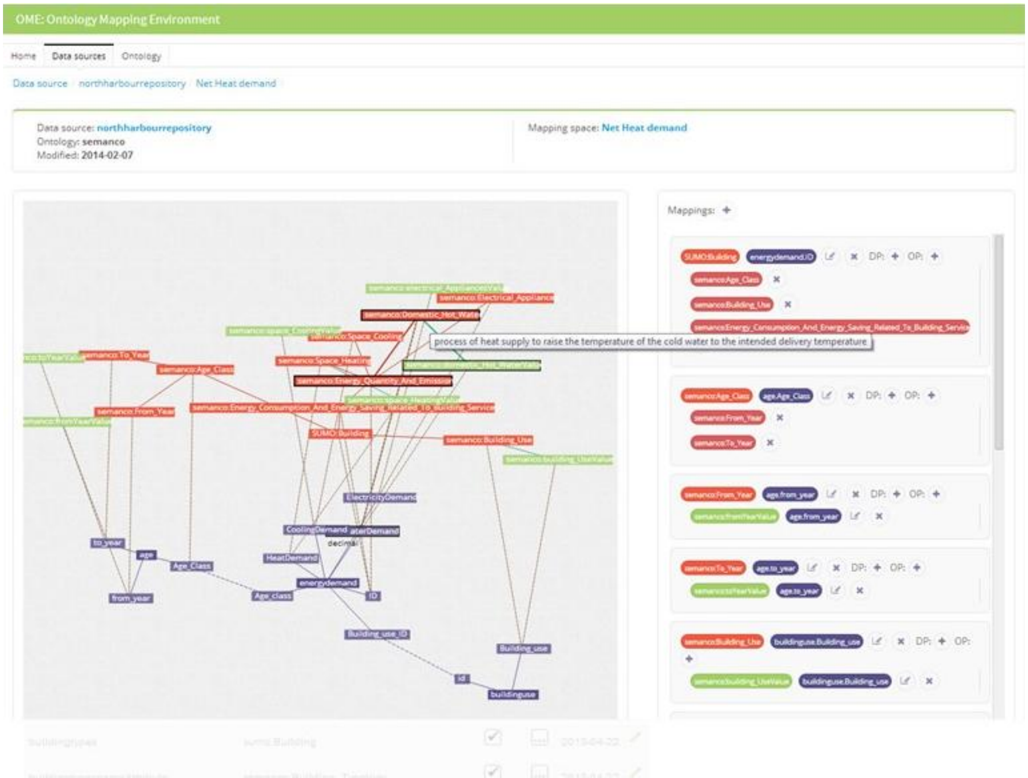

Figure 20. Ontology mapping tools

The support for potential custom mapping was discussed, as well as the need to include aggregation functions in the underlying semantic models. Moreover, there was a discussion on how different granularity of the available data (e.g. low-level data may not be available for the estimation of some KPIs) would affect the estimation of various KPIs used in urban planning. Finally, there was a fruitful discussion among participants on the need to decouple the observations (measurements) from the actual data models in order to avoid potential duplication in the process of "populating" the datasets with new data.

In the following discussion, the relationships of SEMANCO ontology with CityGML were discussed. Claus argued that some of the definitions used in SEMANCO ontology already exist in CityGML. For example, a building is part of a neighbourhood, and this is already established by CityGML. German proposed to make an exercise of ontology alignment between both ontologies. It was mentioned that an OWL ontology of CityGML has been produced by a research OWL created by Prof. Gilles Falquet from the University of Geneva.[8]

Leandro points out that the purpose of SEMANCO ontology is not to compete with any established standard. In SEMANCO, ontologies are used for two purposes: 1. In a conceptual sense, to model the knowledge a group of experts have about an energy problem at the urban level 2. In a pragmatic sense, to integrate distributed data sources from data from multiple domains and applications. SEMANCO's ontology is based on standard terms but it does not attempt to create a standard for the ontologies in the urban energy systems domain.

Raúl García Castro emphasized that an ontology is a specification of a domain and that, therefore, agreed descriptions of the terms used in urban planning are needed, including energy urban systems. It might be necessary to create a working group for that purpose which would work with the objective of creating a W3C standard, as it is the case of sensor technologies.

Koen mentioned the work being done in the UK by the national standard bodies, in particular the British Standards Institution- BSI in close contact with CEN activities. There is a Task Group for standards in smart cities domain.

5.2.2 Session 2 - 11:00 – 13:00: Integration of multiple data sources (Part 2)

Maja Skrjanc presented the work done in the project NRG4Cast concerning data integration. The technology used is data fusion. Data fusion is not straightforward: data sources need to be cleansed before they can be integrated, this is usually problematic. Monitoring data is collected through sensors which generate two types of data: static (the environment where the sensor is located) and dynamic (the activity monitored by the sensor).

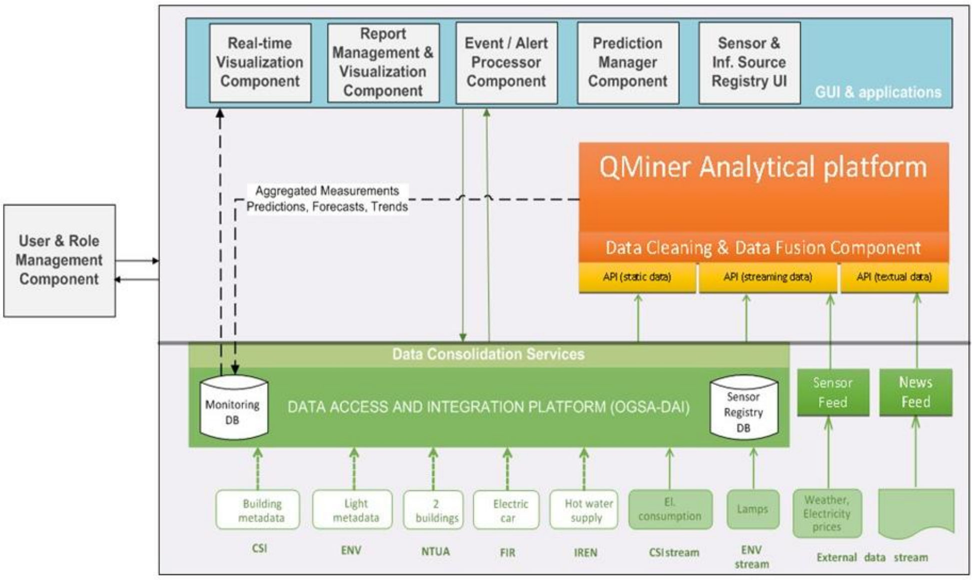

Figure 21. NRG4Cast architecture

Fabian Cretton and Alexander Cotting, from HES-SO Valais, Switzerland, presented their experience working with SPARQL over triple stores (RDB, NoSQL, XML). They have worked with different tools, and would like to share their experience with other experts in the field using these or similar tools. They argued that there is still a lack of information

[8] Available at: http://cui.unige.ch/isi/icle-wiki/ontologies.

concerning the existing tools. They suggested that a community support group would be helpful to share experiences and tools.

Fabian asked if ontology catalogues enabling users to upload ontologies over time already exist. Raúl contended that this is exactly the purpose of the Ready4SmartCities project, to provide tools to facilitate sharing ontologies. Alexander asked if all could use these tools. Koen suggested that it would be useful to track the downloading of datasets from an ontology catalogue, and for this reason, it would make sense to ask for a login.

Conclusions of the session

- Ongoing efforts by respective standardisation bodies (BSI, CEN, INSPIRE, CBNL) shall be taken into account from now on as well as the need to include ongoing activities on Smart Appliances in ongoing W3C Working Groups.
- Although they are strongly related, data standardisation is not exactly the same as ontology modelling. Both aimed to create a shared terminology to conceptualise a specific domain. However, by means of an ontology it is possible to express this knowledge in a formal language so that it can be processed by other applications.
- It is necessary to have transparency in the sharing of knowledge across end-users in the domain addressed in the VoCamp. The knowledge formalised through data models can help end-users to understand the outputs of the systems, thus facilitating decision making.
- Community support is necessary to facilitate the exchange of knowledge and experience among the developers of ontologies in the domain of smart cities and urban planning. This exchange would help the exchange of best practices and the reuse of already developed resources to build semantic models for specific projects.

6 CONCLUSIONS

The VoCamp has revealed the existence of multiple approaches to apply semantic technologies in domains in which the city needs to be understood as a complex system: urban energy efficiency and, in at a more general level, smart cities. Differences among the approaches begin with the understanding of what the city actually “is”: what the city is at the physical level (buildings, streets, infrastructures), but also what activities take place in conjunction with the physical elements. CityGML provides a unified model of what a city “is”. However, beyond the representation of the city as a “static” model, it is necessary to model also the city dynamics: the actions undertaken by specific actors operating on particular city physical structures. Therefore, one of the conclusions to derive from the meeting is that it is necessary to align the development of ontologies with the creation of urban models that encompass both the physical structures that make the city and the activities that take place in it.

To model the behaviour of subsystems (for example, urban energy performance) which are part of an overall urban system it is necessary to capture the multiple relations between data, domains, systems and applications. In principle, ontologies are appropriate mechanisms to create such all-encompassing models.

Although standard data models and ontologies aimed at providing a shared agreed conceptualisation of a particular domain, there are differences between them. Namely, ontology modelling uses a formal language to make the semantics of the data explicit. In this way, machines – through services and applications – can process these semantics and apply inference reasoning mechanisms to the data. Furthermore, ontologies can be reused to build new ones in other contexts and problems.

The work carried out in the SEMANCO project, particularly the energy model (i.e. SEMANCO ontology), has demonstrated the feasibility of using semantic technologies to formalise the knowledge that a group of experts have about particular problems related to energy efficiency of urban areas and to access the distributed data which is needed to model the problem. The SEMANCO ontology has been built upon international data standards to facilitate its further use and development by third parties. Likewise, the tools created in the project to support the ontology building process (the ontology editor and the ontology mapping tools) are generic enough to be used in other projects.

APPENDICES

Agenda

DAY 1: Thursday, February 13th, 2014

08:30 - 09:00	**Reception of participants**
09:00 – 09:30	**Welcome** *Leandro Madrazo, Coordinator SEMANCO project*
	Introduction to the VoCamp series *Dimos Ioannidis, ADAPT4ee/Ready4SmartCities projects*
	Presentation of the 4th VoCamp: objectives and structure *Leandro Madrazo*
09:30 – 09:45	**Participants' introduction**
9:45-10:00	**Presentation of the SEMANCO project** *Leandro Madrazo*
10:00 – 10:45	**Using ontologies to store, share and apply city data in simulation models** *Koen van Dam*
10:45 – 11:00	**Discussion**
11:00 – 11:30	**Coffee break**
11:30 – 12:15	**Urban Information Modelling** *Claus Nagel*
12:15 – 12:30	**Discussion**
12:30 – 13:00	**Introduction to working sessions**
13:00 – 14:00	**Lunch break**
14:00 – 15:30	**SESSION 1 Modelling Urban Energy Systems** *facilitated by Koen van Dam* Presentation of participants (10 minutes each) followed by discussion - Leandro Madrazo (SEMANCO) - María Poveda Villalón (Ready4SmartCities) - Vincenzo Corrado (SEMANCO) - Gonzalo Gamboa (SEMANCO) - Maja Skrjanc (NRG4Cast) - Conclusions and final discussion
.	**Coffee break**
16:00 – 17:30	**SESSION 2 Integration of Multiple Data Sources (part 1)** *facilitated by German Nemirovski* Presentation of participants (10 minutes each) followed by discussion

	- Markus Look (COOPERaTE) - Michel Böhms (Odysseus) - Tomi Räty (VTT) - Luz Maria Priego-Roche (INRIA) - Conclusions and final discussion
18:00	End of first day
21:00	**Dinner at the city (optional)**

DAY 2: Friday, February 14h, 2014

09:00 – 10:30	**SESSION 2 Integration of Multiple Data Sources (part 2)** *facilitated by Claus Nagel* Presentation of participants (10 minutes each) followed by discussion - Álvaro Sicilia (SEMANCO) - German Nemirovski (SEMANCO) - Maja Skrjanc (NRG4Cast) - Fabian Cretton, Alexander Cotting Conclusions and final discussion
10:30 – 11:00	**Coffee break**
11:00- 13:00	**WORKING SESSION** - Identifying and connecting ontologies across scales and domains - The role of ontologies to address the interoperability of data and tools - Strategies and recommendations based on good practices Conclusions
13:00	**Lunch (optional)**

Participants

	Title	Name and last name	Institution	Project
1.	Mr	Markus Look	RWTH Aachen University - Software Engineering, Germany	COOPERaTE
2.	Dr	Jean-Laurent Hippolyte	Cardiff University, UK	Resilient
3.	Prof	Anna Osello	Politecnico di Torino, Italy	Dimmer
4.	Dr	Thomas Liebich	AEC3, Germany	Ready4SmartCities
5.	Dr	Michel Böhms	TNO, The Netherlands	Odysseus
6.	Prof	Asunción Gómez Pérez	Ontology Engineering Group, Universidad Politécnica de Madrid, Spain	Ready4SmartCities
7.	Dr	Raúl García Castro	Ontology Engineering Group, Universidad Politécnica de Madrid, Spain	Ready4SmartCities
8.	Mr	Alberto Abelló	Universitat Politècnica de Catalunya, Spain	Ready4SmartCities
9.	Dr	Pieter Pauwels	Institute for Logic, Language and Computation (ILLC) University of Amsterdam (UvA), The Netherlands	
10.	Dr	Matthias Weise	AEC3, Germany	
11.	Dr	Jérôme Euzenat	INRIA & LIG, France	Ready4SmartCities
12.	Mr	Bruno Fies	CSTB (French research center of the Building/Construction sector), France	Odysseus
13.	Mr	Dimosthenis Ioannidis	Center For Research and Technology Hellas / Information Technologies Institute, Greece	Ready4SmartCities
14.	Mrs	María Poveda Villalón	Ontology Engineering Group, Universidad Politécnica de Madrid, Spain	Ready4SmartCities
15.	Mr	Claus Nagel	virtualcitySYSTEMS GmbH, Berlin, Germany	
16.	Mr	Alexandre Cotting	HES-SO Valais, 3960 Sierre, Switzerland	
17.	Dr	Tomi Räty	VTT - Technical Research Centre, Finland	
18.	Dr	Leandro Madrazo	Engineering and Architecture School La Salle (FUNITEC), Spain	SEMANCO
19.	Mr	Álvaro Sicilia	Engineering and Architecture School La Salle (FUNITEC), Spain	SEMANCO
20.	Mrs	Luz Maria Priego-Roche	INRIA, France	

21.	Prof	German Nemirovski	Albstadt-Sigmaringen University, Germany	SEMANCO
22.	Mr	Fabian Cretton	High Schools of Switzerland - HES-SO Valais, Switzerland	
23.	Dr	Koen van Dam	Imperial College London, UK	
24.	Mrs	Maja Skrjanc	Josef Stefan Institute, Slovenia	NRG4Cast
25.	Mr	Kerem Beygo	Istanbul Technical University, Faculty of Architecture, Department of Urban and Regional Planning, Turkey	
26.	Prof	Vincenzo Corrado	Politecnico di Torino, Italy	SEMANCO
27.	Dr.	Gonzalo Gamboa	CIMNE, Spain	SEMANCO
28.	Mr.	Charbel El Kaed	Schneider Electric, Strategy & Innovation	
29.	Mr.	Bejay Jayan	Cardiff University	
30.	Mr.	Gonçal Costa	Engineering and Architecture School La Salle (FUNITEC), Spain	SEMANCO
31.	Mr.	Joan Pleguezuelos	Engineering and Architecture School La Salle (FUNITEC), Spain	SEMANCO
32.	Mrs.	Anna Florea	Tampere University of Technology, FAST.-Lab	URB-Grade
33.	Mr.	Ammar Aljer	"University of Lille 1 Politech-Lille Engineering school LGCgE Laboratory"	