Report on the REViSITE workshop at the CIB Conference 2011

Interoperability for Improved Energy Efficiency

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EXECUTIVE SUMMARY

Three separate workshops were held at the CIB 2011 Conference in Sophia Antipolis to support the eeBDM efforts in terms of building community support and consensus for a universally acceptable eeBDM. One of these workshops, a REViSITE workshop was organised with some interrelated objectives to the Commission organized workshops. The workshops were:

1. A Commission workshop on current state of the art on Energy Efficient Buildings Data Models
2. A Commission workshop on next steps of eeBDM ontology engineering: Support the eeBDM workshop in terms of building community support and consensus for a universally acceptable eeBDM.
3. The REViSITE workshop on Grid/Building interoperability: Examine the main interoperability touch-points between the built environment and energy grids.

The Building Data Model is regarded essential for advancements in Energy Efficiency in the built environment. The eeBDM and REViSITE workshops identified ontologies, methodologies and tools central to enabling a common BDM definition.

Current research indicates that technologies that are related to Semantic Web (Web 3.0) have best potential for this venture. Ontologies that are part of the European Smart Grid (e.g. mandate 490) projects could be helpful in the design process of an augmented eeBDM. The domain ontologies for the IEC reference framework are mature and may provide examples for the eeBDM development process. The smart grid ontology (the Common Information Model) has been standardised through the IEC 61970-301 document. This formalisation covers maintenance, scoping and versioning in ways that may also be suitable for eeBDM ontologies.

The semantics of the built environment and the grid are connected at a functional level as both domains are part of the same energy flows. In that respect the eeBDM ontology could benefit from smart grid semantics that cover energy efficiency measures. Ontology mappings may be required to effectively exchange information from the grid domain (infrastructure operators, energy market and such) to the built environment (developers, owners, occupants etc.). A mutual approach of grid and build experts would seem beneficial to both sides.

Although the theoretical basis that underpins them was defined some decades ago semantic web and ontology engineering is still in its infancy and there are some issues to address. For example lack of practical experiences with these technologies might make it difficult to assess the validity of publicly available ontologies on the web (sensor models for instance). Additional research is required in order to understand the stability and viability of ontology constructions for eeBDM applications, but the need, value and potential for impact is very much apparent.

ACRONYMS AND TERMS

Acronyms	Description
BIM	Building Information Model
BuildingSMART	Alliance of organisations within the construction and facilities management industries dedicated to improving processes within the industry through defining the use and sharing of information.
CIB	Conseil International du Bâtiment (International Council For Research And Innovation In Building And Construction)
CIM	Common Information Model (IEC 61970-301 standard)
ETP	European Technology Platform
FDI	Field Device Integration
HVAC	Heating, Ventilation & Air Conditioning
ITU	International Telecommunication Union (UN Agency)
IDM	Information Delivery Manual
IFC	Industry Foundation Classes (?)
IFD	International Framework for Dictionaries (buildingSMART)
KNX	Standard network communications protocol for intelligent buildings
OLE	Object Linking and Embedding
OPC	Object Linking and Embedding for Process Control
OWL	Web Ontology Language
RDF	Resource Description Framework
RTD	Research & Technical Development
SRA	Strategic Research Agenda
W3C	World Wide Web Consortium

1. REViSITE INTRODUCTION

The REViSITE project co-ordinates co-operation and communication within the multidisciplinary 'ICT for energy-efficiency' research community in Europe. The focus is on 4 industrial disciplines: manufacturing, construction, lighting and grids. The core of this community are the European Technologies Platforms that represent RTD in these sectors: ARTEMIS, ECTP, MANUFUTURE, PHOTONICS21, SMARTGRIDS. These industry sectors come often together in delivering infrastructures and environments for production, business and living. Together they produce and consume most energy in Europe.

Although versatile statistical information is available on energy consumption in various countries and industrial sectors, there is still limited understanding about the potentials of ICT to reduce it. REViSITE develops a causal model on how ICT can impact on energy consumption in 4 key sectors. Based on available statistical data and, where such data is not available, estimations by experts, the project identifies the RTD priorities for ICT4EE.

The project engages key stakeholders from the 4 sectors to compare and analyse sector specific RTD agendas such as Strategic Research Agendas (SRAs) of the relevant European Technology Platforms (ETPs), European and national RTD initiatives etc. A consolidated roadmap is derived as a synthesis. This roadmap catalyses synergetic RTD and innovation in multiple sectors by pointing to cross-sectoral RTD opportunities in common areas of interest that have the highest impact potential.

An integral component of REViSITE is to explore opportunities for interoperability and standardisation to improve energy efficiency which was the main focus of the workshop presented in this report. A typical example is the interoperability between energy modelling data and building energy management systems (BEMS) and interoperability between sensors data and energy meters. The emerging approach of energy efficiency Building Data Models (eeBDM) and its associated technologies has been explored in this workshop together with the higher level ‘touch points’ between the built environment and grids.

2. OBJECTIVES OF THE WORKSHOPS

"Buildings are responsible for some 40% of the energy consumption in Europe. Along its lifecycle, Buildings are managed by different IT tools. At the design phase, architects use CAD systems, now enhanced with energy efficiency additional software. Ideally, their Energy Modelling data should be exported to the Building Energy Management Systems that optimize energy consumption at operational stage. In turn these systems need to obtain data from sensor clouds and energy meters, and be able to command intelligent white goods and HVAC systems. To facilitate an incremental investment of consumers in energy management appliances a strong plug and play principle is needed. In short, micro and mini renewable sources will be common at every building and need to be integrated into the systems. Finally, prosumers will trade with the Smart Grid their energy consumption or sales to the energy free market with a language that needs to be independent of the utility." [1]

This view is part of the introduction of the eeBDM workshop at the CIB2011 conference [1]. The workshop aim was "to promote the harmonization of approaches across research in this area, as an important milestone towards standards in Energy Efficiency that can be agreed by industry, market players and public authorities and boost the interoperability of the Energy Efficiency IT applications and tools" [1]. The Energy Efficient Buildings Data Model (eeBDM) Workshop is a fundamental step in reaching a valued consensus around standard models for "energy interoperation" in buildings, between buildings, and beyond (over districts and cities).

2.1 Commission workshop on current state of the art on Energy Efficient Data Models

The Commission had collected 21 papers for some of the most relevant contributions on Data Models of the research projects dealing with Energy Efficient Buildings, grouped under 8 themes. The proceedings have been published as a Commission publication. The workshop allowed the authors to summarize their papers, and have a short discussion about them. A list and summary of the papers are included in Appendix 1 of this report.

2.2 Commission workshop on next steps on eeBDM ontology engineering

The presentations outlined in the 8 sessions of the eeBDM workshop decisions regarding the next steps to be taken and this follow up Commission Workshop was dedicated to this task. One clear outcome of the eeBDM workshop was the consensus that ontology engineering is required for the exchange of information in the life cycle of buildings and with other domains. The obvious proceeding objective therefore was the establishment of a unified approach with regard to ontology engineering, the clustering method, the process and the needs for standardisation.

2.3 The REViSITE workshop on Grid and Building interoperability

The REViISTE workshop focused on the “energy interoperation”. This coordination involves multiple buildings and the (smart) energy grid. The input for the workshop is the assumption that a certain amount and form of interoperability between the grid and buildings is required in order to achieve the best possible energy efficiency. The REViSITE workshop focused on identifying the most important touch-points between the grid and built environment in a type of gap analysis. The workshop aimed at formulating an advice on a specific field of expertise to develop in order to bridge the gap.

3. AGENDA AND ATTENDEES

3.1 Agenda: eeBDM Presentations Track

The eeBDM Workshop took place during the CIB 2011 Conference organised in Sophia Antipolis organised by CSTB. A total of 21 papers (see the whole list in appendix1) were presented during this workshop along 8 different sessions:

- Session 1. Ontological Engineering State of the Art
- Session 2. Green Building Information Modelling
- Session 3. Energy and Behavioural Modelling and Simulation at Facility Management
- Session 4. BEMS Integration Platforms & Ontology's
- Session 5. Ontology's for Heterogeneous Physical Devices
- Session 6. Middleware for EupP (Energy using or producing Products), White goods, HVAC, Storage and Micro Renewables
- Session 7. Prosumers Micro Energy Trade Semantics
- Session 8. eeB Data Models collaboration space

The number of participants to the Workshop could be estimated around 35/40 persons. A brief synthesis of this track is presented in section 4.1

3.2 Agenda of the Commission workshop on next steps on eeBDM ontology engineering

The follow-up session on the eeBDM workshop was moderated by Rogelio Segovia, Scientific Officer of the European Commission. The subjects were:

- What is the direction in terms of a unified approach to ontology development?
- How should the clusters and areas of ontologies to be organised?
- What is a suitable Process? (Both for the technologies and methods)
- What are the relevant Standardisation organisations to be involved?

3.3 Agenda of the REViSITE workshop on Grid and Building interoperability

The REViSITE workshop on the touch-points between the built environment and the energy distribution grid was moderated by Nico Vlug (KEMA). The subjects were:

- Introduction and setting the scene for grid and buildings interactions.
- Workshop to identify relevant touch-points, technology gaps and priorities
- Conclude on next steps, follow-up and dissemination.

3.4 Attendees of the workshops 2 and 3

Initials	Attendee	Organisation
	Alvaro Sicilia	Arc la Salle
AF	Antonio Feraco	Innova, Italy
	Adrian Noguero	Technalia, Spain
BF	Bruno Fies	Centre Scientifique et Technique du Bâtiment
CSF	Carmen Suárez-Figueroa	Universidad Politécnica Madrid
	Cesar Valmaseda	Cartif, Spain
	Christos Malarazos	Hypertech S.A., Greece
	Dimitrios Rovar	Technical University of Crete
DK	Daniel Kuhn	Fraunhofer Institute for Applied IT, Germany
	Ivan Perez	Technalia, Spain
JE	Jérôme Euzenat	INRIA & LIG, Grenoble, France
KE	Keith Ellis	Intel Labs Europe, Ireland
	Klaus Kabitzsch	Technische Universität Dresden, Germany
KM	Karsten Menzel	University College Cork (UCC)
	Kuo-Ming Chao	Coventry University, UK
MD	Marcus Damm	Vienna University of Technology, Austria
	Matja König	University of Ljubljana, Slovenia
MP	Matti Paljakka	VTT Technical Research Centre, Espoo, Finland
	Nazaraf Shah	Coventry University, UK
NVl	Nico Vlug	KEMA Consulting, Arnhem, NL
RS	Raimar Scherer	Technische Universität Dresden, Germany
RSg	Rogelio Segovia	the European Commission
SF	Steven Firth	Loughborough University, United Kingdom
	Sylvain Marie	HPC-SA / Raycreatis
TH	Tarek Hassan	Loughborough University, United Kingdom
	Tasos Tsitsanis	Hypertech S.A., Greece
TL	Thomas Liebich	AEC3, München, Germany
	Thomas Papapolysis	Hypertech S.A., Greece
	Thomas Rollman	Technische Universität Darmstad, Germany
WS	Willem Strabbing	KEMA Consulting, Arnhem, NL

4. WORKSHOP PROCEEDINGS

4.1 REViSITE synthesis of eeBDM Track

This chapter aims to provide in layman's terms a synthesis of the ontology and built environment concepts, methodologies and technologies presented at the eeBDM Track of the CIB2011confrenece.

Figure 1 below represents a layered representation of the various concepts in relation to the Built Environment Life cycle and specifically the energy flow throughout same. Layers closer to the Built environment represent those layers that are conceptually nearer to the physical with subsequent layers moving closer to the abstract or application layers.
In the figure there is a difference between protocols, which levels they span and in the way they span those levels. For example, the KNX protocol is built up from the field level to the management level but BACnet is more focused at the management level and is less defined at the field level.

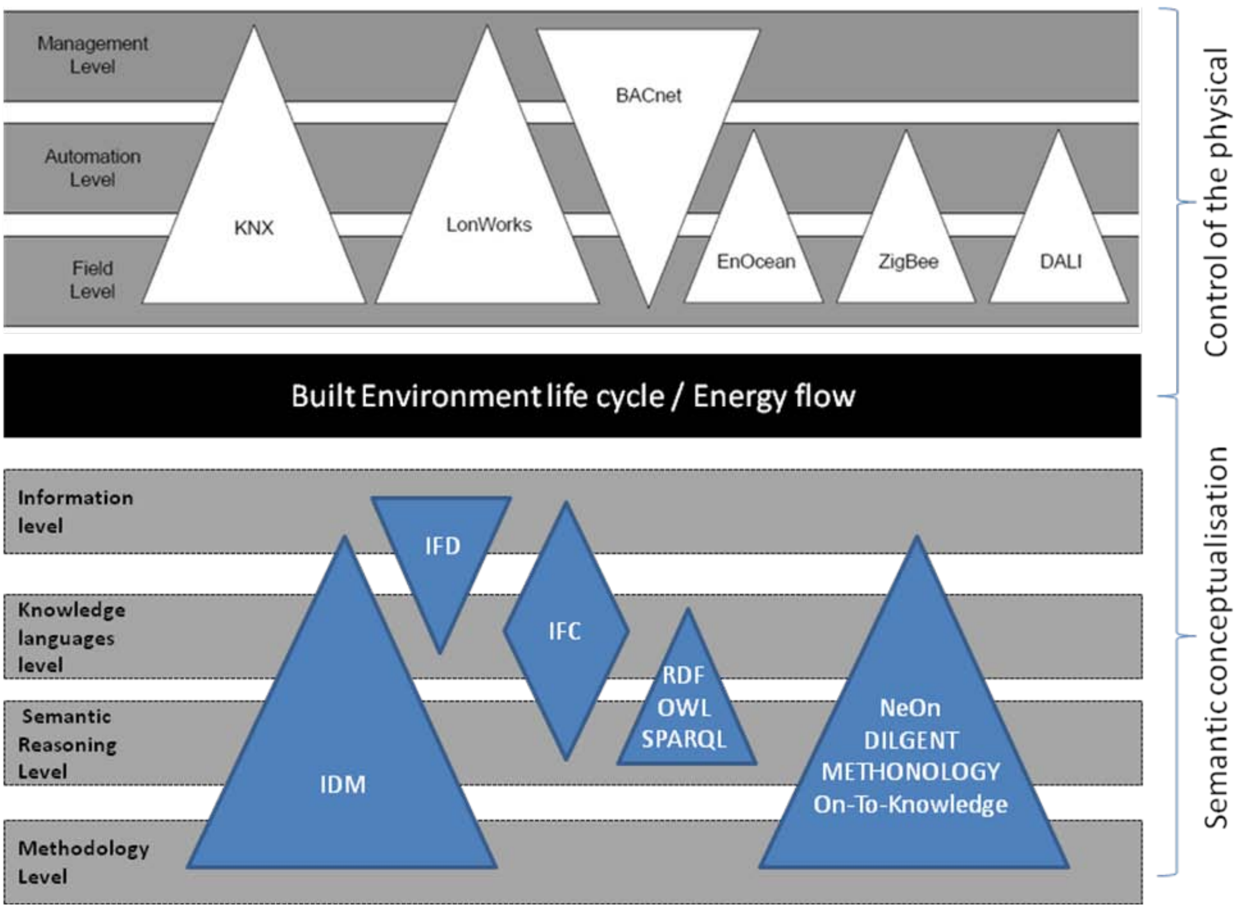

Fig 1: Mapping Ontology & Built Environment concepts, technologies, methodologies

While the classical building automation technologies will be crucial in realising energy efficiency gains, semantic ontology methodologies and languages and the linking of same will be paramount in allowing both domain and non-domain actors [e.g. Grids, service providers] to understand the information flows and elements that constitute the built environment.

4.2 Proceedings of the Commission eeBDM next steps elaborations workshop

4.2.1 What is the direction in terms of a unified approach to ontology development?

The eeBDM workshop on the day before shows a preliminary conclusion that there appears to be common support for "Semantic Web" (Web 3.0). Challenges on ontology engineering were then elaborated by CSF.

Some projects use ontologies and semantic ideas but on an isolated way. Every project is building own information models without sharing (e.g. sensors models could be uniform). Projects in the building sector should share the models with other domains and focus on re-using existing ontologies eventually extending it with additional specifics following the core approach of the World Wide Web Consortium (W3C). One possible approach is to transform standards into ontologies. RSg asks for the preference on methodology (Such as methontology). CSF is using the NeOn tools. WS (Kema) commented that bringing domains together in this context was important.

JE presents his views on ontology engineering. There is a need to interoperate, rather than integrate, within the same domain and across domains. He recommends to connect with other sources of information as it is not a matter of merging. A new initiative called 'linked data' is using semantic web technologies (RDF/OWL) to publish data of various types: government data, geographic data, etc. Using such technologies is the way to go: start by sharing data and models with others in other domains and take advantage of data published by others. Linked data principles command to expose data in RDF and use OWL for describing the vocabulary.

MP elaborates on the eeBDM workshop. He is surprised with the lack of knowledge or discussion on OPC, he deemed it very useful and promising technology for coupling live data with static structural data is the installation. OPC will also help getting measurements from domain objects. There are issues with regard to FDI standardisation, Open PLC and OPCUA (for smart grids). Enhancement of the conversation across projects requires common platforms. But it is difficult to chose platforms. 'Linked data' has great potential and has data sets which are similar. MP suggests starting with terms & descriptions.

4.2.2 How should the clusters and areas of ontologies to be organised?

RSg asks for the robust core ontologies and the way to cluster the areas that were identified in the eeBDM workshop. KM sates that ontologies require domain knowledge and suggests to split based on building type. Another option would be to split the domains along the lifecycle: models for the devices and the parts and models for the operation phase. TL proposes to identify the initial scope of different ontologies first (to identify overlaps, etc.).
Jérôme does not agree with the suggested scoping because it usually prevents reusing data.
KM has doubts on the practicalities on following the life cycle and transferring data from one stage to the other. RS states that data models should go to types of buildings – start with

description of the data model and the ontology (that includes the meta data). He suggests to start with activity models.
RSg suggests to take a life cycle approach – but the ultimate goal is energy saving. Perhaps an agreement can be discussed for an ontology to describe energy flow. Talking to devices is very generic – not same as the building. Take substance of energy model as a separate discussion — take sensors as a different group. WS suggests focusing on energy efficiency-knowledge about data models and that it is needed across different domains and mentions the BIM & CIM cluster. KM highlights the difference between the objective of reducing CO2 emissions and that of achieving energy savings and whether we need to achieve one objective or both.

RSg advocates to focus on energy flow – but then build on it. The appliance level might be a depth too far. JE asks if sharing data is important? He thinks we need to get to the intention of the designer, their models are on the table but we don't understand the thinking that led to the design. RS: BIM and sensor models – are independent? Sensor models should be linked to the building model. Which Standardisation bodies need to be involved? KM suggests: structure the discussion to share among the stakeholder groups. CSF would like to establish the current state of the models in the area that are needed – how they are divided? Analyse current models and find out the mindset of the people who developed the models. This could be done by analysing ontologies and papers to identify the similarities.

4.2.3 What is a suitable Process? (Both for the technologies and methods)

RSg made some suggestions to build on the eeBDM workshop.. He proposes to put information on the public website to analyse. Need to create a methodology such as concluded in the ITU & the recent calls by EC in terms of establishing more quantitative common means of assessment. RS suggests to form groups – input of their results to be more interoperable. The website can be a combination of public area in addition to workshops. An approach is sending an ontology on before hand to study then go to a workshop to discuss.

4.2.4 What are the relevant Standardisation organisations to be involved?

Comment on standardisation bodies? TL: we need to separate industry associations from standardisation bodies, Agree something, then go to industry group to sanity check before going to SO.

BuildingSMART versus standardisation associations such as ISO, CEN. BuildingSMART is such an industry association having already bi-lateral agreements with ISO. Then what level we target? Suggestion to: agree on something in a group then go to organisations such as ISO. RS suggest to identify active experts in the standardisation bodies in order to introduce the ideas. KE suggests to establish a study group within the SO's to select a proper process.

4.3 Proceedings of the REViSITE workshop on Grid/Building interoperability

4.3.1 Introduction and setting the scene for grid and buildings interactions.

NV (KEMA) sets the scene for future developments of the smart grid. The Joint Working Group on Standards for Smart Grids (CEN/CENELEC/ETSI) envisions use-cases that involve both the energy grid and buildings to coordinate [4]. The definition of a smart grid therefore includes “generators, consumers and those that do both”. These cases would anticipate the semantic domains of the grid and build environment to allow for mutual exchanges of information. The touch points in that sense will primarily be communication touch points described in terms of the conceptual relationship.

4.3.2 Workshop to identify relevant touch-points, technology gaps and priorities

The introduction of the workshop includes an example of a touch-point that has implications in the planning phase and the operational (energy management) phase. The participants are asked to provide touch-points that will be required to achieve the best possible energy efficiency. The results of the workshop are listed below. The touch-points that were identified have been documented along with a description, the actors involved and comments (if any).

Touch-point	Description	Actors	Comments
Generic measurement and control	The application of sensors and actuators find relevancy in the energy flow and the conjunction of multiple buildings (districts or neighbourhoods)	Occupant Energy market	In support of Home Energy Management Services [5]
Systems collapse (prevention)	The grid operator is able to disconnect buildings from the grid to avoid outages or restore from black-out.	Occupant Grid operator	Regulated action with financial compensation scheme.
Load (demand) forecasting	The energy supplier needs to establish demand from buildings in order to maintain the energy balance and optimise the use of renewables.	Occupant Energy market	Foremost a commercial responsibility.
Solar production	Fit PV generation from local solar installations on buildings in the energy trade portfolio of the supplier and the operations of the grid owner.	Occupant Energy market Grid operator	

Touch-point	Description	Actors	Comments
Time of Use tariffs	Communicate financial consequences and options of the energy market to the building occupant. May involve smart appliances and user preferences.	Occupant Energy market	In general: Business models for renewables
Local Storage	Business case development of local storages involves the inhabitant of the building, the grid owner and the energy market.	Occupant Energy market Grid operator	Has touch-points in both utilisation and building design phase
Supply prediction	The demand of the building depends on renewable generation. The business case depends on energy prices and user preferences	Occupant Energy market Power production	
Carbon footprint (calculation & verification)	Targeted environmental performance depends on energy fuel mix and building materials	Developer Power production	
Privacy	Smart meter data of usage contains behavioural patterns that could benefit energy supplier and grid operator	Occupant Energy market Grid operator	
Grid Load	For local (micro) grids to anticipate on demand / supply fluctuations the grid load is required. Buildings would share (peak) load (energy) management functions and react to load trends.	Occupant Grid operator	
Direct & indirect Feedback	The building occupant is informed by the energy market on usage, tariffs and options using displays, invoice details or other means	Occupant Energy market Grid operator	
Grid connection	The building developer agrees with grid owner on the characteristics of the grid connection of a building	Developer Grid operator	
Smart Meter	The building occupant and energy supplier agree on Smart Meter settings, preferences and the use of data.	Occupant Energy market	
Human behavioural aspects	The grid owner and supplier will anticipate on certain behavioural aspects of the building user such as number of inhabitants, size of family, age etc.	Occupant Energy market Grid operator	
Urban planning	Building developers and grid owners have a joint responsibility with respect to grid loads and capacity plan	Developer Grid operator	

4.3.3 Conclude on next steps, follow-up and dissemination.

In order to achieve such comprehensive coordination between the grid and build environment an elaborate exchange of information is required. The grid operators and energy market parties all conform to the IEC reference architecture. This information architecture includes a domain ontology called the “Common Information Model” (CIM). The CIM is standardised through the IEC 61970-301 document. The workshop supports the conclusion that a semantic linkage needs to be established between the CIM and the semantics of the build environment (BIM and such). The Über-ontology describes the links that cross the grid and building borders and provides for the mutual semantic definitions and containments [4].

The difference in maturities of CIM & BIM may prove fruitful, as the connection could be framed in terms of the Energy flow. Linking information flow to energy flow between the actors could provide for the most abstract Über-ontology. New research would be needed to investigate the gap between the two environments and the ability to bridge the gap in terms of ontology engineering.

5. CONCLUSIONS

5.1 Main Findings

It appears after the different exchanges and presentations that both sectors (Energy Grid and Buildings) have developed their own models. For the energy grid, the corresponding model is the CIM mentioned in the previous chapter. For the construction sector, the BIM is the common and agreed approach to elaborate models that will support the collaboration and exchange among partners .We can compare these CIM and BIM as two ontologies or two separate approaches to elaborate ontologies.

An ontology is a formalisation of a system for a given purpose, it is design each time to support a specific usage. As main drawback, re-using ontology or merging ontologies into a single one is often difficult. There are of course some high level ontologies, generic enough (a representative example is SUMO - Suggested Upper Merged Ontology - http://www.ontologyportal.org/) that provide a common root in order to merge ontologies but the difficulty to find gateways among the concepts of different ontologies remains. This corresponds to a "top-down" approach, difficult to use effectively.

One of the approaches for merging ontologies was to remove the semantic links among concepts and concentrate only on the vocabulary (flat list of concepts) and rebuild upon them a new ontology. This approach can be considered as a "bottom-up" approach and costs time and resources…

A third approach has been presented also based on the integration of existing models (Paper "Requirements and Gap Analysis for Bim Extension to an Energy Enhanced Bim Framework"). This approach is based on the idea of reusing multiple models, via a dedicated model specifying the "touch points" among the different models. It is worth noticing that all the recommendations made are based on existing standards (IDM approach).

Some models presented (like the one in the paper "Energy and Behavioural Modelling for managing energy resources in residential buildings") clearly mentioned (or made use of) classes (in modelling terms) or concepts(in ontology domain wording) that could be considered in both sectors like "Users", "Devices", "Buildings", etc... Even if theses notions (or concepts) are similar in both sectors, they probably will not be considered from the same angles and therefore will have different facets depending on the context they are used. The IFD is mentioned as an emerging technical solution to tackle this kind of issue. In a narrower scope, the "ontology-based device description" (Paper: "Ontology models and design patterns for building automation") provides a framework to elaborate layered ontologies. This promising work opens the door to the development of small sized ontologies that could be considered as many "Lego" bricks that could be easily re-used / derived /aggregated in order to form big ontologies expressive enough to represent current systems.

5.2 Results of the Commission workshop on next steps on eeBDM ontology engineering

The elaborations on the eeBDM allow for the design of a preliminary roadmap for the development of such data model. This chapter contains the topics that could be part of the next steps towards a common eeBDM. A specific consensus in the community would be helpful in order to agree on priorities and approach. The topics are listed in random order:

- Create an overview of the available ontologies and assess if the current models suffice for the eeBDM functional scope
- Define the requirements for the ontologies and tools that will be used to design and maintain the eeBDM ontology framework
- Elaborate a multi layer map (on the basis of the picture presented in chapter 4) displaying:
    - What are the “touch points” between the two sectors
    - What are the most promising technologies and methodologies related to Grid/Construction/Devices that will enable to setup gateways among these fields and made possible a unification of these heterogeneous models under a common platform;
    - What are the standards behind these technologies

This elaboration will be made step by step with exchange and validation from the REViSITE community experts (by exchange of emails, skype conferences and eventually physical meetings).

The findings of the Commission workshop on eeBDM were already peer reviewed by Thomas Liebich & Jerome Euzenat who provided some elaboration on their views and some suggestions to improve Fig 1 which have been already incorporated. Further validation of the results is planned to take place by direct interviews with some selected experts

5.3 Results of the REViSITE workshop on Grid and Building interoperability

Functional touch-points between the grid and the built environment exist that seem to require a common view on the information exchanges and the related semantics. The smart grid project already defined domain ontologies that are part of an IEC standard. These ontologies have limited support for the built environment. Both semantic domains, the smart grid and the built environment, would ease the exchange of information in support of energy efficiency measures with appropriate semantic definitions.

6. REFERENCES

[1] Foreword to the Proceedings of the eeBuildings Data Models-Workshop by Colette Maloney, Head of Unit European Commission

[2] The REViSITE project summary by Tarek Hassan (Loughborough University) and the REViSITE consortium (2010)

[3] Cib2011-W78-W102-Booklet - Proceedings of the CIB workshop in Sophia Antipolis (France, 2011)

[4] Final report of the CEN/CENELEC/ETSI Joint Working group on Standards for Smart Grids (May 4th, 2011)

[5] Home Gateway Initiative. Use cases and architecture for a Home energy management service. HGI-GD017-R3, August 5th, 2011

APPENDIX 1: EEBDM WORKSHOP – LIST AND SUMMARY OF PAPERS

Session I: Ontological Engineering State of the Art

1.1. Paper: Essentials In Ontology Engineering: Methodologies, Languages, And Tools

1.2. Paper: Semantic technologies and ontology matching for interoperability inside and across buildings

Session II: Green Building Information Modelling

2.1. Paper: A Framework Approach for EEBIM and Heterogeneous EEAnalysis Data Models

2.2. Paper: Requirements and Gap Analysis for Bim Extension to an Energy Enhanced Bim Framework

2.3. Paper: Ontology models and design patterns for building automation

Session III: Energy and Behavioural Modelling and Simulation at Facility Management

3.1. Paper: Energy and Behavioural Modelling for managing energy resources in residential buildings

3.2. Paper: Energy and Behavioural Modelling and Simulation for ee-Buildings Design

3.3. Paper: Knowledge Management for Integrated Energy Demand and Supply in Buildings, Campus and District

Session IV: BEMS Integration Platforms & Ontology's

4.1. Paper: The IntUBE (Energy Information) Integration Platform

4.2. Paper: Open source platforms for the semantic integration of cross-disciplinary data

4.3. Paper: Pervasive energy measurements for Buildings monitoring

4.4. Paper: Method for Validation of Building Simulation Results using Sensor Data

Session V: Ontology's for Heterogeneous Physical Devices

5.1. Paper: Enabling energy efficiency through device awareness using ontologies

5.2. Paper: Towards a Generic Middleware for Developing Ambient Intelligence Applications

Session VI: Middleware for EupP (Energy using or producing Products), White goods, HVAC, Storage and Micro Renewables

6.1. Paper: Middleware for energy aware appliances

6.2. Paper: An EuP Classification for Partially Decentralized Domestic Energy Management

6.3. Paper: Energy Conservation Recommending Semantic Services

6.4. Paper: Iterative Model-based Identification of Building Components and Appliances by Means of Sensor-Actuator Networks

Session VII: Prosumers Micro Energy Trade Semantics

7.1. Paper: Modeling of Flexibility in Electricity Demand and Supply for Renewables Integration

7.2. Paper: Prosumer interactions for Efficient Energy Management in SmartGrid neighbourhoods

SessionVIII : eeB Data Models collaboration space

8.1. Paper: ICT4E2B Forum: eeB Data Models collaboration space

The section in the next few pages provides a summary of these papers.

eeBDM - ICT for a Low Carbon Economy EE Building Data Models

Session I. Ontological Engineering State of the Art

1. Essentials In Ontology Engineering: Methodologies, Languages, And Tools

"An ontology is a formal, explicit specification of a shared conceptualization. Conceptualization refers to an abstract model of some phenomenon in the world by having identified the relevant concepts of that phenomenon. Explicit means that the type of concepts used, and the constraints on their use are explicitly defined. Formal refers to the fact that the ontology should be machine-readable. Shared reflects the notion that an ontology captures consensual knowledge, that is, it is not private of some individual, but accepted by a group".

Methods and methodologies which can be used for building ontologies:

- The NeOn Methodology (Suárez-Figueroa)
- METHONTOLOGY (Gómez-Pérez)
- The On-To-Knowledge methodology (Staab)
- The DILIGENT methodology (Pinto)

Language(s) which should be used to implement an ontology:

- RDF -- Resource Description Framework (Klyne and Carroll).
- RDF Schema -- RDF Vocabulary Description language (Brickley and Guha).
- OWL -- the work of the W3C Web Ontology Working Group (Dean and Schreiber).
- OWL 2 -- An extension and revision of OWL (Motik et al).
- SPARQL (Prud‟ hommeaux and Seaborne).

Tool(s) which give/s support to the ontology development process:

- The NeOn Toolkit (http://neon-toolkit.org/)
- Protégé (http://protege.stanford.edu/)
- TopBraid Composer (http://www.topquadrant.com/products/TB_Composer.html)

2. Semantic technologies and ontology matching for interoperability inside and across buildings

Context information management frameworks:

- Open, so that new devices and applications can be involved in the environment. It must thus rely on well accepted standards for expressing information which guarantees that components will be able to interoperate.
- Dynamic, so that these devices and applications can be taken into account dynamically. This requires that it can represent new types of information and that it can match these representations so that old parties take advantage of new ones and vice versa.
- Minimal, so that the framework does not put a non realistic burden on application and device developers. This requires to keep minimal the computing resources and specific interfaces needed for using this framework.

Ontology matching

- Content-based matchers
- Context-based matchers

Ensuring interoperability

- Automatic: it is not possible to rely on the user to directly help matching, and indirect help cannot postulated because there will not always be users;

- Fast: when a process needs an alignment it cannot wait for hours to have the results, hence, either matching should be processed online or precomputed alignments must have been stored;
- Correct: it is rather important the provided alignments be correct even if some level of fault-tolerance is possible; it is less important that it be complete.

Three possible approaches to obtain such alignments:

- Online embedded matching
- Ontology alignment service
- Collaborative alignment

Session II. Green Building Information Modelling

1. A Framework Approach for EEBIM and Heterogeneous EEAnalysis Data Models

- An information framework for an energy-information enhanced Building Information Model (eeBIM) with special emphasis on the data model for energetic building analysis is complemented by a SOA-based ICT system.
- An Integrated Virtual Energy Laboratory (IVEL) platform which can be beneficially applied in all life-cycle phases of a building for design decisions, control purposes, system identification and prognosis.

The standardised IFC data model has become the most prominent BIM model. However it does not yet cover the information which is necessary for the energy analysis of buildings.

The overall approach is to design an open SOA platform based on BIM, BIM-CAD and BIM-FM, extended by services for intelligent access to BAS and advanced energy analysis tools, built upon a common conceptual modelling basis, the envisioned eeBIM. The main development steps comprise:

- Specification of the eeBIM and inter-linking it with all other needed data into a coherent multimodel framework.
- Complementing the eeBIM-based multi-model framework with an ontology that would allow managing complex IVEL platform interactions, and
- Extending existing applications so that they can seamlessly exchange the required data in both directions.

2. Requirements and Gap Analysis for Bim Extension to an Energy Enhanced Bim Framework

The EU project HESMOS (2010-2013) develops an industry-driven holistic approach for sustainable improvement of energy performance in PPP projects through integrated design and simulation, while striving to increase the quality of the building and to decrease life cycle costs. A central issue of the HESMOS platform is the life cycle integration of services and tools based on a consistent model-based approach derived from thoroughly studied end user requirements and existing gaps on the one side, and a preset high-level multi-model concept on the other side.

The main gaps that exist in current practice:

- The lack of a common data repository based on a consistent building information model
- The lack of software interoperability due to the absence of integrated standards based platform solutions, and
- The insufficient use of simulation (based on BIM) and monitoring (based on installed sensors in the BAS) during the whole life cycle.

Several ICT challenges with regard to the envisaged BIM-based framework:

- The disruptive nature of the related processes, taking place over dozens of years but not in continuous manner and not with the same actors and tools
- The heterogeneous and distributed nature of the information resources (building design data, building automation data, climate data, material data, equipment and product catalogues, usage statistics etc.) that need to be maintained during the whole building life cycle
- The heterogeneous and distributed nature of the software tools (CAD and FM systems, general simulation frameworks, specialised energy solvers, cost calculation tools)
- The multiple data models that have to be integrated and mapped to the requirements of the involved services and tools
- Various legal issues related to warranties, information access, security, and so on.

A common modelling framework requires:

- A coherent eeBIM modelling approach, taking into account all energy related data models and respective information resources
- Appropriate extension of BIM to include necessary energy relevant extension, but without overburdening the model with highly specialised narrow-domain concepts
- Integration of existing building automation models such as BacNet, LON or KNX into the eeBIM framework
- Bi-directional transformation methods enabling the modelling transitions BIM □eeBIM, BAS □eeBIM, eeBIM □Simulation Models, eeBIM □Life Cycle Cost Models.

3. Ontology models and design patterns for building automation

- Interoperability in BAS
- Ontology concepts for building automation systems

Session III. Energy and Behavioural Modelling and Simulation at Facility Management

1. Energy and Behavioural Modelling for managing energy resources in residential buildings

An analysis of the various kinds of data needed to be collected and stored for the purpose of advanced building energy management systems (BEMS). These include:

- Building behavioural data about the actual building operation that can be acquired by means of embedded sensors
- User behaviour data (user activities…) that have proven to have a great influence on actual building energy performance
- Energy prices evolution, and
- Weather forecasts.

A global and conceptual model of these data that is consistent and linked with standard BIM representations like IFC or gbXML files, and that can be seen as a further extension of BIM that covers some FM issues.

This is presented within the context of the FIEMSER (Friendly Intelligent Energy Management System for Existing Residential Buildings) EC-funded project that aims at developing an innovative energy management system for existing and new residential buildings (single-family houses, multi-dwelling building blocks).

2. Energy and Behavioural Modelling and Simulation for ee-Buildings Design

The state of the art on energy and behavioural modelling and simulation tools for EE Buildings design.

Energy-intelligent constructions incorporating innovative ICT (self-organized integrated Frameworks of sensors, actuators, meters etc) will present the ability to efficiently adapt to occupant needs and preferences, maximize energy performance while at the same time comply to overall business requirements. This can be further realized through the fusion of two (currently disjoint) worlds: a) Building Information Modelling (BIM) and b) Business Process Modelling (BPM), having occupants as the main catalyst. This fusion, among other obvious advantages, will also present the ability for enhanced diagnostic and renovation of existing constructions and also generate infrastructures and simulation environments to assess variants of environmental performance of buildings, tools for dynamic building evaluation at run-time, and allowing optimisation based on multi-dimensions / multi-criteria constraints.

3. Knowledge Management for Integrated Energy Demand and Supply in Buildings, Campus and District

Introducing a case study on UCC: Knowledge management and Building Information Model.

Session IV. BEMS Integration Platforms & Ontology's

1. The IntUBE (Energy Information) Integration Platform

IntUBE defines three data/information models or "ontologies":

- A Building Information model (BIM) (static as-planned)
- A Simulation Model (SIM) (dynamic as-planned), and
- A Performance Information Model (PIM) (dynamic as-operated).

2. Open source platforms for the semantic integration of cross-disciplinary data

This paper presents the Sefram and Simantics platforms developed by VTT and their approaches to data modelling and integration under the IntUBE project funded by the European Commission FP7.

3. Pervasive energy measurements for

Buildings monitoring

Giving an overview of energy monitoring challenges with the HOMES project based on how energy data are retrieved, how they are classified and what additional data can enhance the monitoring experience namely the Building Information Modelling (BIM) and what are the expected benefit of this integration. It focused on autonomous sensors and an optimized energy management system to provide energy monitoring solutions and observing behaviour changes. The pertinence of the BIM as a metadata provider was discussed; in the data collection the sensor addressing vocabulary was detailed. The raw data from pilot sites are merged with other data (metadata, reference and process data) through a Business Intelligence (BI) process for extracting useful information to help understand, give meaning and take action.

4. Method for Validation of Building Simulation

Results using Sensor Data

The paper discussed a method of validation, which will provide a means of comparing measured data (e.g. sensors and weather data), and simulated data (e.g. near future simulations). From this comparison, value is added from correction of simulation results, and/or input to simulation parameters. Further worth can also be provided by gaining knowledge for creation of simulation profiles which are difficult to predict before construction & operation. Additional value can also be derived from identifying conditions of poor results and relevant factors which can be corrected. SIM ontology has been developed as a SIM operational form. Openness of form is provided by allowing for results from more than one simulation tool, whereby any information not created can be left blank in the form. The form can be expanded upon if any other simulation software has results not already covered or listed. The process for providing useful raw data has been completed; future research will focus on providing more value from this data.

Session V. Ontology's for Heterogeneous Physical Devices

1. Enabling energy efficiency through device awareness using ontologies

Use of semantic technologies, such as ontologies is a solution for the problem that systems devoted to improve energy efficiency tend to work in heterogeneous environments, interfacing with different devices from different manufacturers.

Ontologies are formal descriptions of the concepts and relationships that can exist for an agent or a community of agents, usually inside a specific domain. They define entities, properties, interactions, actors and basic concepts that compose the common vocabulary for all members of the domain they define. One interesting property of ontologies is that they are extensible. That means that existing concepts can be refined, and new elements can be added. Some frequent uses of any ontology are:

- To share common understanding of the structure of information among people or software agents
- To enable reuse of domain knowledge
- To make domain assumptions explicit
- To separate domain knowledge from the operational knowledge
- To analyze domain knowledge

Brief description of eDIANA reference architecture and the device awareness problem associated to it is given. Then the methodology applied in the development of the ontology is provided. In the context of eDIANA the main objective of the ontology is to enable device concentrators to recognize devices connected to the Cell and discover their interfaces, the domain of the ontology will be focusing in Cell level devices. For the sake of completeness, the ontology will also cover MacroCell level concepts. The development process of the ontology for device awareness was an iterative cycle. Each cycle consisted of three steps: (i) brainstorming step, (ii) categorization step, and (iii) property definition step. Simulation has proven to be a successful approach. Ontologies not only provide a common understanding of the domain and all the devices it implies; but also supports the seamless evolution of the domain when new elements are added without affecting already running systems.

2. Towards a Generic Middleware for Developing Ambient Intelligence Applications

The LinkSmart middleware presented here for developing and Ambient Intelligence (AmI) defines an abstraction layer on top of heterogeneous communication protocols which solves the AmI compatibility issues. It provides services to application developers, hiding the complexity of underlying device specifics, so that service interfaces are decoupled from the network protocol. Furthermore decoupling the application development from device programming brings advantages with regards to modularity, reusability and extensibility. It provides a transparent and secured communication channel that takes into account mobility and dynamic addressing of devices and related services. It utilizes a semantic modelling technology for representing devices or any aggregation of devices that allows application developers addressing network nodes semantically. LinkSmart middleware software architecture and design, device classifications, and the use of ontologies for semantic application development are described in the paper. It introduces the Semantic ModelDriven Architecture (SeMDA), which aims to facilitate application development and promote semantic interoperability for services and devices. LinkSmart offers a set of extended features such as security, context awareness, quality of service, distributed storage, etc. These features help application developers build high quality applications within a short time.

Session VI. Middleware for EupP (Energy using or producing Products), White goods, HVAC, Storage and Micro Renewables

1. Middleware for energy aware appliances

This paper describes an experience on the development of a user friendly/ consumer-centric middleware platform based on the OSGi framework for the control and scheduling of operation of energy-consuming appliances and service providers" access equipment.

The proposed solution implements an innovative appliance control system that presents options for optimizing appliances" operatio n and scheduling of events. It is also able to act automatically in a single-building level depending on the model of the building embedded in the controller.

What is presented is an ICT architecture that facilitates non-compulsory demand-side management measures under a time-varying electricity tariff system. The architecture manages to reconcile two apparently conflicting goals: control ultimately rests with the human consumer and at the same time the consumer is not overburdened with the need to perform constant optimizations or worry about frequent tariff changes. Future Internet enablers that can be leveraged to deploy such an architecture have been identified and the basic interoperability interfaces were described.

2. An EuP Classification for Partially Decentralized Domestic Energy Management

Classification of Energy using Products (EuPs) was used in the SmartCoDe project. The classification is specific to a parrticular application scenario in the domestic / small business area with renewable energy resources nearby but a usual public grid connection also available. We outlined the options for demand side management (DSM) for each class, and sketched a partially decentralised energy management (EM) approach where part of the control decision remains with the wireless sensor/actor nodes within the EuPs. For optimal utilisation of renewable energy resources by managing the demand of appliances in private neighbourhoods and small offices/businesses; the core idea is to use wireless sensor/actor nodes to control electrical appliances in a way that local renewable energy resources like wind energy and photovoltaics are maximally exploited. Forecasts for the local renewable energy production are pre-processed by a central energy management unit which generates abstract cost functions. These cost functions might capture also other aspects like tariffs or load forecasts, and are then issued through the wireless network. The final decision making is then shifted to the sensor/actor nodes, and is based on these cost functions as well as the class of the appliance which is controlled. To this end, a classification of electrical appliances is presented which is suitable for the application scenario, and it is discussed how each class can be handled regarding energy management.

3. Energy Conservation Recommending Semantic Services

The goal of the DHEMS project is to monitor energy consumption across a wide range of households and analyse the energy consumption data in order to give users relevant real-time recommendations to conserve energy. As a result this leads to a need to process and convert the collected energy consumption data into meaningful information and semantics, which can be reasoned over with other services to derive appropriate advices.

The semantic system adopted is composed of subsystems. The system architecture provides a conceptual framework view of the structure. The main architectural components are data server, knowledge and reasoning, which operate cooperatively in order to broadly provide the following functionalities:

a- Allow household to view alerts concerning their energy consumption targets and other abnormal energy consumption by appliances and possible remedial actions/advice

b- Allow household to rate energy saving tips and submit their thoughts and experiences on efficient energy consumption

c- Enable household to browse energy saving tips based on various grouping such cooking and washing etc, and also individual appliance level

d- Upon household login display more personalized and useful tips

e- Provide interactive menu for households, which allow them to interact with system by providing answers to various questions concerning missing information in the system. It works like a diagnostic tool and tries to find the underlying causes of abnormal energy consumption

In terms of implementation, the semantic system draws upon ontology for domain knowledge representation, expert system for intelligent reasoning, SQL Database for data storage and management, Java Enterprise Edition for server side programming. The operation of the semantic system is organised into three layers, known as service demand layer, service broker layer and service provider layer. The semantic system uses mixed initiative interaction and brings household as an actuator in control loop whenever necessary.

4. Iterative Model-based Identification of Building Components and Appliances by Means of Sensor-Actuator Networks.

To enable the indirect integration of legacy home/building appliances and building components that do not have a network connection to the home/building network, to make it possible to monitor and partially control them. A mechanism and system for the iterative identification and self-configuration of these devices through a shared backplane of networked sensors and actuators available in the building is proposed. So as to acquire fine-grained real-time information about the operation of these entities and to control them in return. A description of a system that identifies and monitors these non-networked entities using a shared sensor-actuator backplane is given. The identification is performed incrementally on the basis of a hierarchy of predefined models that approximate the behaviour of the target entities according to relevant criteria.

This makes it possible to integrate these devices and interface them through a software proxy as if they were state of the art networked devices, thus extending the range of the network and the associated middleware towards all kinds of physical entities of that make up the home/building. These entities are supposed to be described in a model repository and a domain-specific ontology. The matching of the entities being discovered in the home/building environment to these known models is done by analogue pattern matching, instead of requiring an exact match as would be the case with a standard digital networks protocol, so that it lends itself to iterative approximation. Examples were provided for typical home appliances and other subsystems of the home/building that may be dealt with in a similar way. The architecture and OSGi-based implementation of this system have been provided a validation prototype.

Session VII. Prosumers Micro Energy Trade Semantics

1. Modeling of Flexibility in Electricity Demand and Supply for Renewables Integration

For electricity system Production/consumption) the use of the flexibility in electricity demand for balancing with unpredictable electricity supply is described as a possible way forward to mitigate the challenges. The business advantages for using flexibility and some pricing mechanisms that provide financial incentives for using flexibility by the consumer and the balance responsible party in the grid is also described.

The MIRABEL system which deals with generating offerings of flexibility in load and distributed generation provides the means to issue so-called *flex-offers* indicating these power profile flexibilities, e.g. shifting in time or changing the energy amount. The system is able to dynamically schedule flex-offers in near real-time, e.g. in case when the energy production from renewable energy sources, such as wind turbines, deviates from the forecasted production of the energy system.

A BEMS takes input from various sensors in the building and controls devices in order to achieve an optimum between various objectives, such as:

- usage of resources to minimize the import of electricity from the smart grid,
- maximize the use of the buildings own energy generation,
- maintaining the comfort level within the desired limits,
- reducing the cost of energy consumption.

The concept is to be applied in a BEMS, i.e. using flexibility for matching demand and supply in the smart grid to further reduce cost of energy consumption through offering and negotiation of flexibility to be utilized by the smart grid such that smart grid balance is improved and penetration of intermittent renewable energy sources can be increased.

The model is used for deriving scheduling algorithms that make use of the flexibility model. These algorithms also use forecasting and aggregation techniques on flex-offers in order to decrease the complexity and increase the chances of matching the electricity of demand and supply.

2. Prosumer interactions for Efficient Energy Management in SmartGrid neighbourhoods

Investigation of the interactions of SmartGrid prosumers by considering the local context of the users and their behaviour in a neighbourhood within a smart city is conducted to provide an information and communication driven infrastructure for the users to interact and e.g. buy and sell energy on online marketplaces. With hope to enable to better manage the energy in the highly dynamic electricity network of the future.

The NOBEL used state of the art technologies to dynamically obtain and process information from current available installed equipment. This is achieved by implementing bidirectional communication with all involved entities, process the information with respect to consumption and production and automate decisions to be made network-wide. The project also develops a service oriented framework that will allow easy flow of information among the prosumers and the enterprise systems in order to foster more energy efficient processes. This implies the development/extension of a middleware – i.e. a set of application independent services – that enable the distributed capturing, filtering and processing of the energy related data. The same services will ease enterprise wide inclusion and allow for better cross-layer collaboration which will lead to holistic optimization strategies. Once the basic infrastructure supporting real-time monitoring and management, as well as the respective brokering services, then scenarios demonstrating how energy efficiency can be achieved will be realized. Some real world tests are also planned.

Session VIII. eeB Data Models collaboration space

1. Paper: ICT4E2B Forum: eeB Data Models collaboration space

Identification and reviewing the needs in terms of research and systems integration as well as at accelerating implementation and take-up. Through community building activities, a better understanding, a closer dialogue and a more active cooperation between researchers, end-users/practitioners, building owners, technology-suppliers, and software. ICT4E2B Forum bases its road-mapping activities on the outputs of REEB project that has already developed a high-level roadmap on ICT for Energy Efficient Buildings. This should show a clear, shared and agreed vision of the different stakeholder involved in the whole value chain. A mapping of the sector-specific priorities into a common view and vocabulary, thereby enabling communication and understanding between experts in different sectors that need to join forces in order that fundamental improvements in energy efficient buildings can be achieved. All in support of defining future research directions as well as in channelling efforts, while favouring consensus buildings on the roadmap itself.

Within this framework a relevant aspect is covered by Data Models, which represents an enabling infrastructure for the actual implementation of future ICTs in the EeB context and that covers all relevant priority areas identified by the project. Considering this important aspect ICT4E2B Forum created a specific collaboration space for sharing relevant results and discussion about EeB Data. Models, in order to foster the discussion and extract relevant future scenarios and prioritization for the roadmap from this relevant area of research.

In this paper the relevant reference elements and the proposed approach to reach the final goal of the project are presented.