ICT 4 E2B Forum - European stakeholders' forum crossing value and innovation chains to explore needs, challenges and opportunities in further research and integration of ICT systems for Energy Efficiency in Buildings

Deliverable D2.2: Prioritised gaps

Document Details

Due date of Deliverable:	2011-10-31
Lead Beneficiary:	VTT Technical Research Centre of Finland
Dissemination Level (*):	PU
Version:	1
Document Name:	D22_Prioritised gaps.doc
Preparation Date:	2011-10-24
Prepared by:	Nusrat Jung, Johanna Nummelin, Matti Hannus (VTT) Andrea Cavallaro, Christian Mastrodonato (DAPP) FrancescPelegrin (ATOS) Oskar Nilsson (SCHNEIDER) StamatisKarnouskos (SAP)
Verified by:	N.N. (DAPP)

(*) Only one choice between CO (Consortium), CR (Partners Concerned), PU (Public)

Project Contractual Details

Project Title:	ICT 4 E2B Forum-European stakeholders' forum crossing value and innovation chains to explore needs, challenges and opportunities in further research and integration of ICT systems for Energy Efficiency in Buildings
Project Acronym:	ICT 4 E2B Forum
Grant Agreement No.:	260156
Project Start Date:	2010-09-01
Project End Date:	2012-10-31
Duration:	26 months

SEVENTH FRAMEWORK PROGRAMME

Executive summary

Starting from the already existing European strategic research roadmap to ICT enabled energy-efficiency in buildings and constructions (REEB) the first objective of this deliverable is to report the identified gaps between the updated state of the art and vision of the future after approximately 10 years from now. Secondly, a prioritisation of identified research needs is presented excluding the on-going and recent past research initiatives.

The work was conducted by project partners, who collected key topics from previously produced deliverables and identified research gaps between the state of the art and visions for each of the five categories. Recently finalised and on-going research efforts were taken into consideration based on the available public information. Due to the limitations of this information, any evaluations about the actual realisation of the research results of these endeavours could not been made. The experts completed the identified research gaps and prioritised research topics.

The first part of this deliverable consists of the consolidated information about each category, as well as the identified gaps. The REEB project formed a solid ground about the future research topics upon which this work updates, as well as seeks validation from wider research and development community.

The second part consists of prioritisation by different categories and stakeholders. Prioritisation questionnaire was developed and first implemented in two workshops held on July in Genoa and Brussels. The experts were asked to prioritise the presented research topics and identify missing gaps. The work continued after workshops when key experts were asked to fill the questionnaire. Currently questionnaire is available in internet and collection of prioritisations continues. After the two workshops a prioritisation matrix was collected and used as a basis for analysis.

Different stakeholder groups have naturally different preferences in relation to research topics. More than one third of respondents considered that following topics must be advanced as soon as possible:

- Building and district modelling
- Simulation
- Intelligent HVAC
- Smart lighting
- ICT for microgeneration and storage systems
- Smart metering
- Performance analysis and evaluation
- User centric design
- Building management systems
- Plug & play connections
- Access to knowledge

At this phase no further analysis were conducted due to the limited amount of responses and bias identified among the respondents. The dissemination work will continue in able to get results that more fundamental conclusions can be drawn. The analysis presented in this deliverable will be used as background information when building up the draft roadmap for future RTD activities in D2.3. The prioritisation work will continue and final results will be represented in later stages of forming the roadmap.

Table of Contents

1 Introduction

Purpose

This document represents the identified gaps in research and technology development (RTD) by comparing the identified state of the art (D1.2) and on-going European research activities (D1.3) in field of Information and Communication Technologies (ICT) and Energy Efficient (EE) buildings. The identified gaps also considered the envisioned futuristic scenarios (D2.1) to compare present technology to desired efficient technology for future.

Document structure

The document is structured in the following chapters:

Section 1: Introduction, presents the purpose and general background of the deliverable D2.2 Prioritised gaps.

Section 2: Gap analysis addresses the identified gaps by collecting relevant information previous from deliverables D1.2, D1.3 and D2.1 defining the needed research and development.

Section 3: This chapter focuses on prioritisation of RTD areas by different stakeholders focusing on the ranking of RTD categories for roadmap development.

Section 4: Conclusion focuses on the compliance with Description of Work (DoW) and delivers the main findings followed on with acronyms, references and appendices (separate file).

Contributions of partners and experts

VTT Technical Research Centre of Finland (later VTT) was the main responsible partner for the preparation of this document (Chapter 1 and 4). Chapter 2 representing gap analysis was divided among partners and driven by them as follows:

1. Tools for integrated design and production(lead by VTT)
2. Intelligent & Integrated Control (lead by Schneider Electric, later Schneider)
3. User awareness and decision support (led by D'Appolonia)
4. Energy Management and Trading (led by SAP)
5. Integration technologies (led by ATOS Origin, later ATOS)

Chapter 3 representing prioritisation by different stakeholders is also contributed by partners as follows:

1. Design and construction companies (led by VTT)
2. System providers(led by Schneider)
3. Users(led by D'Appolonia)
4. Energy Suppliers(led by SAP)
5. ICT and service providers (led by ATOS)

D'Appolonia prepared and organised two workshops held in Genoa and Brussels, where selected experts were involved to prioritise the future RTD areas in realm of ICT for energy efficient buildings. The gap prioritisation questionnaire used in the prioritisation workshops was prepared by D'Appoloniaand VTT (see appendix 7.3).

Baseline

The main inputs taken under consideration at the start of the work were:

- REEB: European strategic research Roadmap to ICT enabled Energy-Efficiency in Buildings and constructions [1]
- Energy Efficient Buildings PPP Multi-annual roadmap and longer term strategy [2]
- Previous deliverables from ICT4E2B
  - D1.2 Initial analysis of the state-of- the-art [3]
  - D1.3 Initial analysis of research projects [4]
  - D2.1 Application scenarios [5]
- Results obtained from previous three workshops on future application scenarios (face-to-face interaction)
- Organised two workshopson gap prioritisation

Approach to gap analysis

We identified gaps in RTD by comparing the identified state of the art (D1.2) and on-going research (D1.3) to the vision on the future application scenarios (D2.1). The template for gap analysis was provided by VTT (see appendix 7.2).

On the bases of obtained gaps, a prioritisation matrix was prepared, where within main categories the identified research areas were introduced. The experts in two workshops, held in Genoa on July 4th and Brussels on July 12th, 2011, were provided with a prioritisation questionnaire (see appendix 7.3) to rank the areas of RTD topics (categories and research topics) later used as analysis in defining the key-priority areas to be considered for planning future research in ICT for energy efficiency (EE) in buildings.

Two kind of prioritisation techniques were used in workshop:

1) The prioritisation matrix was based on MoSCoW method [6] to identify stakeholder's interest areas. MoSCoW is a prioritisation technique to reach a common understanding with stakeholders by the significance they place on different topics. It includes a rating method from 1 to 4 where:
   - *4 = MUST have this as soon as possible*
   - *3 = SHOULD have this in near future*
   - *2 = COULD be nice to have if it is easy to adopt*
   - *1 = NOT now but maybe in the future*
2) The second was generated through group discussion in the workshops where the experts were asked to prioritise the research areas within each thematic area by 100€ test i.e. sub-dividing the amount as per significance of research topics. Furthermore, reasoning and motivation for assigning priority to identified key-research area was also rated and discussed.

Based on qualitative analysis of the obtained ranking of categories and research topics, the priority RTD areas are further expanded as perceived by stakeholders in group of:

- Designers, construction companies, material and product suppliers
- System providers
- Users
- Energy suppliers
- ICT and service providers

The outputs received during the prioritisation process will alleviate the recognised research areas for the roadmapping process of ICT4E2B, serving the basis to expand into a broader vision to optimise and further integrate the prioritised areas for research in ICT enabled EE of buildings.The obtained results of the deliverable will be further used in D2.3 to derive the short, medium and long term research and development priorities to fill the identified gaps.

2 Gap analysis

The aim was to identify gaps in priority RTD topics in realm of information and communication technologies (ICT) for energy efficiency of buildings. The results obtained from (the three workshops of application scenarios, two workshops on gap prioritisation, the previous deliverable D1.2Initial analysis of the state of the art, the D1.3 Initial analysis of research projects and the D2.1 Future application scenarios) were considered as baseline to identify gaps in this deliverable D2.2.

The objectives of gap analysis are as follows:

- Structuring all inputs and results into categories
- Bridge the gaps from state of the art towards the broader vision of future ICTs
- Lead to the clear progress beyond the state of the art
- Not to repeat already on-going RTD (analysis in D1.3 was done in order to avoid the repetition of currently on going RTD efforts in the research worldwide)
- Prioritise the identified gaps with the contribution of experts

2.1 Tools for integrated design and production

State of the art	Recently finished and on-going projects	Gaps	Vision
1.2 Design			
Development of building EE tools apart from mainstream BIM-CAD modelling software's; Limited data interfaces; Data models to enable integration of LCA	BE AWARE BRIDGE CLIMAWIN DEHEMES LITES POBICOS	Multiple independent tools leading to heterogeneous systems; EE and ICT related components are not considered as primary concern in practice.	Standardised design tools for energy efficiency; Forecast of energy consumption at initial design phase.
1.2 Production management			
Multiple software tools are used in practice for process and production management; Local law, regulation and contractual practices.	HESMOS PICODICON	Lack of interest and knowledge at consumer level; Practice of traditional methods; Few Experts with combined knowledge of ICT in EE and AEC domain.	User awareness; Building materials and ICT related building components to contain minimal information on energy impact e.g. eco-labelling; Interoperability between enterprise resource planning (ERP) and building information models (BIMs)
1.3 Modelling			
BIM for data representation allowing multiple users; BIM based energy analysis.	BE AWARE BRIDGE DEHEMES	Linkage between BIM tools and ICT related products; BMS and ICT related applications are not seen as part of building design process.	Autonomous control systems and ICT related building components to be integrated in BIM software's and tools. Intelligent model checkers for BIM validation purpose.
1.4 Performance estimation			
Existing tools are not contractually practiced and regulated; data flow among chain of tools used for performance estimation.	BEAWARE; CLIMAWIN DEHEMES ; HESMOS HosPilot; InTUBE ;LITES ReVisite; SAVE ENERGY	Multiple ICT products and systems; Complex tools for monitoring; Lack of direct user incentives	District level energy monitoring in municipalities; Encourage introduction of policies on personal carbon allowances

2.1.1 Design

There is a need to draw focus on development of building EE tools apart from mainstream building information modelling (BIM) and computer aided design(CAD) software as the independent BIM-CAD tools focus on detail design methods with limited data interfaces. Thus the powerful data models are required to enable integration of life cycle analysis (LCA) in the design process.

Current on-going research identified in D1.3 through the EU projects and programmes reflects the accretion of product model-based data management tools, where concerns of improving business processes, infrastructure and life cycle management are being tackled. However, multiple independent tools and products are continuously raising the concern on heterogeneity between systems where holistic EE urban design is a still a concept and minimal actions are being taken to regulate EE measures. The identified gaps suggests a vision where EE and ICT related components would be primary concern of design processes to achieve the energy consumption forecast at initial design stages.

2.1.2 Productionmanagement

Multiple software tools are used in practice for process and production management but issue of compliance among them remain the same where the governing national market operates on local law, regulation and contractual practices adding to the fact of in-house tools or provide by small and medium enterprises (SMEs).

Practice of traditional methods of on-site, off-site and logistic in production management by professionals in architecture, engineering and construction sector (AEC) is still prevalent due to inconsistencies occurring in new methods and tools. The change has to initiate from the top-down level in EE buildings increasing the productivity and quality. In near future the building materials and ICT related building components will contain eco-labels increasing user awareness and ensuring the EE of built environment.

2.1.3 Modelling

The notable gap identified during the research is tool-based linkage betweenBIM software and ICT related building components. Broadly, building management system (BMS) and ICT related applications are not seen as part of building design process, rather expensive retrofitting is executed in the operational phase as per consumer’s requirement. Use of BIM is the significant technology for data representation in AEC industry, thus it is foreseeable to use BIM as single point of application supported by multiple users giving rise to interoperable collaborative environments where autonomous control systems and ICT related building components would be integrated in BIM software and tools supporting EE and LCA of a building.

2.1.4 Performanceestimation

The primary concern observed in the current research and development is the ability to monitor the energy consumption of existing buildings at urban level. Existing tools (multiple ICT-enabled appliances and systems) in the market for performance estimation of a building are not considered reliable enough to be contractually practiced and regulated, thus the need to develop appropriate data flow among chain of tools used for performance estimation is necessary. Consumers need simple tools to control and ability to monitor their energy costs to understand the incentive of increasing building properties life span. It can be foreseen that the energy consumption would be monitored at an urban level leading to introduction of policies based on personal carbon allowances.

2.2 Intelligent and integrated control

State of the art	Recently finished and on-going projects	Gaps	Vision
2.1 Automation & control			
Independent, mature and standardised solutions for control.	• Integrated electronic system • Intelligent sensor-based data monitoring • Development of nano-materials • Use of smart sensors and Radio Frequency Based Technology (RFBT) • High performance devices with electronic operation of an auto-regulated natural ventilation system and electronic insulating night blind powered by solar power.	• Holistic control strategies and common conceptual framework for interoperability • Incorporate external resources such as weather forecast and smart grid for predictive control	The future buildings, along with their components, equipment, and their environment will communicate and be able to provide information on their status ubiquitously. This real-time available information will be interoperable via common protocols for holistic automation & control. The whole building will be supervised by intelligent systems, able to combine information from all connected devices, from the Internet or from energy service providers in order to efficiently control HVAC (heating & cooling), lighting, and hot water systems along with energy production, storage and consumption devices inside the building, taking into account the users' needs and wishes.

2.2 Monitoring			
Measurements stored in trend logs and signals such as energy consumption and temperatures supports information for user interfaces and automatically generated reports.	• New innovative domestic smart metering technology • Local platforms • HW platform using a combination of wired and wireless sensing technology • Design and implementation of an energy resources virtualisation environment and appropriate semantics	• Sensors with sufficiently low cost and ease of installation for wide adoption.	Monitoring relying on the instrumentation of the building with smart meters, other sensors, actuators, micro-chips, micro- and nano-embedded systems that allow collecting, filtering and producing information locally. This huge amount of distributed information could be consolidated by a global monitoring system, incorporated or in liaison with the Building Management System.
2.3 Quality of service			
Basic self-diagnosis is commonly available in automation control products. Advanced services that attempts to identify failures based on historical building data.	• Research on diagnosis on data such as detection of malfunctioning equipment, non-optimal performance of buildings • Secure communication inside the built environment	• Transmission protocols • Self-diagnosing products • Diagnostic algorithms for holistic building behaviour	Quality of service covering issues such as improved diagnosis (allowing the monitoring and control system to auto-detect failures in the connected devices) and secure communications (ensuring full integrity of all data exchanges between applications).
2.4 Wireless sensory networks			
On-going standardisation work of wireless sensory networks	• Wireless sensor nodes • Sensor networks able to collect real-time information	• Low cost wire and battery-less energy harvesting sensors. • Communication protocols • Commissioning procedures • Interoperability between systems of different vendors	Achieve completely autonomous sensors in terms of energy supply thanks to advanced energy harvesting technologies. The sensors need to be standardised, low cost and easy to install and commission.

2.2.1 Automation & control

Currently there are mature and standardised solutions for control of heating, ventilation, lighting and blinds. These controls are however commonly independent and the benefit from coordination with e.g. access control and power distribution is usually unexploited. On-going research includes:

- Development of an integrated electronic system to monitor different building models, technical building services, electronic devices and operations in order to optimise and integrate all maintenance functions.
- Development of intelligent sensor-based data monitoring.
- Development and novel use of nano-materials it aims to increase energy performance in heating, ventilation, air conditioning (HVAC) and lighting systems, and to improve indoor air quality using catalytic purification.
- Use of smart sensors and Radio Frequency Based Technology (RFBT).
- Developing novel high performance devices with electronic operation of an auto-regulated natural ventilation system and electronic insulating night blind powered by solar power.

Following gaps were identified:

- Develop holistic control strategies that integrate all building dimensions, and develop a common conceptual framework for interoperability with the definition of a relevant set of services for sensors/actuators.
- Incorporate external resources such as weather forecast and smart grid for predictive control.

2.2.2 Monitoring

Monitoring is a standard component in a modern BMS. Measurements used for building control are also stored in trend logs and signals such as energy consumption and temperatures supports information for user interfaces and automatically generated reports.

On-going RTD efforts include the development of new innovative domestic smart metering technology and local platform showing the resource and device integrator part, enabling the interoperability of sensors, actuators and meters. System implementation will require the development of a HW platform that will use a combination of wired and wireless sensing technology to facilitate easy and cost-effective retrofit of devices and infrastructure into existing premises to monitor and control energy usage.Design and implementation of an energy resources virtualisation environment and appropriate semantics to be used for building energy management applications.

Identified gap is the development of sensors with sufficiently low cost and ease of installation for wide adoption.

2.2.3 Quality of service

Some basic self-diagnosis is commonly available in automation control products: for instance the controller may detect if the wire of the temperature sensor breaks and will be able to set up a procedure to fix the problem. When a building automation system is available, there is usually a large quantity of self-diagnosing functionality with associated alarms. An alarm can be issued if for instance the equipment is faulty or the temperature is out of range, etc. There are also more advanced services that attempts to identify failures based on historical building data.

Identified gaps include the development of transmission protocols that satisfy requirements (in terms of reliability, security, privacy etc.), products that are self-diagnosing, and diagnostic algorithms for holistic building behaviour.

2.2.4 Wireless sensory networks

There are some wireless technologies for building automation currently on the market. So far, none of them shows interoperability between different vendors, however there is significant standardisation on-going, for instance in the ZigBee Alliance and Internet Engineering Task Force (IETF).

On-going RTD efforts consists of the development of wireless sensor nodes including multi-source energy harvesters, small factor fuel cells, and energy efficient RF front end with radio triggering capability, as well as sensor networks able to collect real-time information detecting environmental and maintenance-oriented parameters of performance from lighting and HVAC services.

Identified gaps are the development of low cost wire and battery-less energy harvesting sensors, communication protocols to assure multi-vendor interoperability and support of battery-less devices, and commissioning procedures to ensure easy installation.

2.3 User awareness and decision support

State of the art	Recently finished and on-going projects	Gaps	Vision
3.1 Performance management			
Standardised methods and indicators are available; Performance audits, labelling and continuous commissioning are supported by recorded data of real time performance.	BEAWARE; BRIDGE; CLIMAWIN COST-EFFECTIVE; DEHEMS ECOLIFE; eDIANA; E-HUB; EnPROVE; EnRiMa; HOSPILOT; INTUBE; NOBEL; REViSITE; SAVE ENERGY; SMART HOUSE/SMART GRID; V-CITY.	Too many tools developed for each of the EE management and design area; National legislation implies the use of national metrics that cannot be shared outside the National limits.	Heterogeneity BMS that can easily interact with: Modelling tools, Performance specification evaluation tools and Decision support tools
3.2 Visualisation of energy use			
Awareness for users; Visual interface must be implemented in order to be easily accessible from users; Motivate and support behaviour changes; Cost reduction.	AIM; BEAWARE; BRIDGE; DEHEMS; EnRiMa; INTUBE; MESSIB; NOBEL; SAVE ENERGY; SMART HOUSE/SMART GRID; TIBUCON; V-CITY.	Inability to assess aggregate performance data based on user/stakeholder performance; Lack of intelligent energy consumption visualisation technology for user.	Use of World Wide Web providing smart, simple user interface to decrease energy consumption and billing costs; User oriented information and best practices systems.
3.3 Behavioural change			
User awareness on need to increase the use of smart meters for real time metering; Multiple technologies are available but the usage and incentives are not know by many users.	AIM; EnRiMa; FIEMSER; Green Buildings; H-KNOW; ICT21EE; NOBEL; SEEMPubs; V-CITY.	Inabilities to modify or set up the parameters of electronic equipment, automated pilots are needed.	Use of energy banks for users by provision of real-time energy databases ensuring the need to change behaviour patterns to avoid high energy consumptions.

2.3.1 Performancemanagement

Standardised methods and indicators are available for assessing and benchmarking the energy performance of buildings, systems and components. But it still remains an open issue the fact that it is fundamental to have regulation that allow to obtain a reference Metric that can be used across different European countries. Too many tools developed for each of the EE management and design area. Some of these are less connected to each other where performance audits, labelling and continuous commissioning are supported by recorded data of real time performance. Furthermore, national legislation implies the use of national metrics that cannot be shared outside of national limits. Performance management will be ensured by the definition of heterogeneity Building Management System (BMS) that can easily interact with:

- Modelling tools
- Performance specification and evaluation tools
- Decision support tools

This tool, exploiting an energy parameters database, should help the different stakeholder to better define the level of efficiency of the building.

2.3.2 Visualisation of energy use

There is the need to make occupants aware on how their activities will influence energy use from short and long term perspectives. Visual interface must be implemented in order to be easily accessible from users. Motivate and support behaviour changes by highlighting other factors that affect energy usage (like demographics, family composition). The reduction of technological costs, (related to buying and installing energy equipment's in buildings and usually carried on by final user), will help to increase the diffusion of these equipment's, the development of efficient distributed architecture like smart grid, and the global reduction of energy consumption.

For different users/stakeholders with different behaviour and different knowledge regarding computers, accessibility and usability of intelligent visualisation system is required. It is necessary for end users to assess aggregate performance data based on their own energy consumption in order to increase the level of awareness.

Visualisation of energy use will be ensured by using a World Wide Web accessible, smart, and usable interface, and also providing them useful suggestions to manage their habits to decrease energy consumption and billing costs. Again to identify the level of individual knowledge that each user (such as occupant, inhabitant, and building's owner) must have about the buildings in which he lives or works in. This kind of knowledge should be referred to the followings subjects:

- Geographical information: the place where the building is built, in order to be able to identify the features of the building itself, like orientation to the sun, wind exposure and so on, but also information the external environment
- The inner comforts: for instance the electric equipment's, which are installed in the building, that increase the daily level of well-being for users living or working in the building and are directly or indirectly used by end user.

2.3.3 Behavioural change

Most of the technologies already available should be used to improve the level of user awareness. But clear information should be provided to users of buildings about energy consumption it is necessity to increase the use of smart meters for real time metering. Final user should be able to modify the setup of their electric equipment modifying some parameters of their own system; in this manner the electronic equipment should be automatically piloted to the right configuration.

Behavioural change will be ensured by using an efficient and smart tool for real-time energy consumption management. This tool, exploiting an energy bank database, should help the users to obtain a real-time assessment of the efficiency of their daily energy actions.

2.4 Energy management and trading

State of the art	Recently finished and on-going projects	Gaps	Vision
4.1 Building energy management			
▪ Isolated solutions available dealing with energy management in buildings. ▪ Limited number of smart appliances. ▪ Solutions are not interoperable.	SmartHouse/SmartGrid NOBEL, AIM, BeAWARE, BeyWatch, CLEAR-UP, eDIANA, E-Hub, EnerSIP, EnRiMa, eSESH, FIEMSER, H2SUSBUILD, HOBNET, INTUBE, PEBBLE, SEEMPUBS, SPORTE2, etc.	▪ A need to provide interoperable energy management solutions ▪ Building collaboration with their users (adaptive behaviour) ▪ Cross-system collaboration within a building ▪ Lifecycle management of energy services	Integration of intelligent devices and accurate forecasting by context information integration will enhance the flexibility in building energy management.Interoperable energy management solutions beyond standalone systems/buildings will help to adjust to users' behaviour as well as external needs.
4.2 District energy management			
▪ Energy Monitoring solutions available ▪ Energy info is available in silos of solutions for the different district systems ▪ Lack of energy services for the citizens	NOBEL, ENERGY WARDEN, HESMOS, LITES, PIME'S, SmartCoDe, V-CITY, etc.	▪ Real-time monitoring of energy ▪ Real-time energy management ▪ Collaborative district-wide approaches ▪ Energy management for emerging trends e.g. buildings and electric cars ▪ Security and Privacy ▪ District wide energy services ▪ Modelling and simulation tools	Real-time energy management is depending on Key Performance Indicators and real-time demand-response depending on local resource availability. Buildings collaborate with the local district for energy efficiency.
4.3 Smart grids and the built environment			
▪ Smart metering ▪ Energy monitoring services for citizens	AIM, BeAWARE, BEST Energy, BeyWatch, NOBEL, SmartCoDe, SmartHouse/SmartGrid, etc.	▪ Real-time demand-response ▪ Metering analytics ▪ Integration of buildings with prosumers ▪ Integration with energy market ▪ Security and Privacy	Buildings collaborate with each-other and external smart grid market.

2.4.1 Building energy management

There are several, also commercial isolated solutions available dealing with energy management in buildings. There are also a limited number of smart appliances available, but the solutions are not interoperable.

There is a need to provide interoperable energy management solutions beyond standalone systems, building collaboration with their users (adaptive behaviour), cross-system collaboration within a building, and lifecycle management of energy services.

2.4.2 District energy management

At the moment there exist energy monitoring solutions, but they are not real-time). Also available energy info is in silos of solutions for the different district systems and there are hardly any energy services for the citizens.

There are several gaps in research identified, for example real-time monitoring of energy, and energy management, collaborative district-wide approaches, energy management for emerging trends e.g. buildings and electric cars, security and privacy issues, district wide energy services, and modelling and simulation tools.

2.4.3 Smart grids and the built environment

Currently smart metering and energy monitoring services for citizens areunder development.

Identified gaps included the lack of real-time demand-response, metering analytics, integration of buildings with prosumerswith energy market, as well as the need to develop the security and privacy issues.

2.5 Integration technologies

State of the art	Recently finished and on-going projects	Gaps	Vision
1.1 Process integration			
The former represents an advanced, ICT-based framework which facilitates collaborative design through communication, data and knowledge sharing and negotiation.	*	Lack of applications providing control of parallel processes; lack of collaboration between different design disciplines; Need of smart workflows	The dynamic nature of design projects requires parallel processes, smooth workflow and tight control.
1.2 System integration			
Multiple solutions representing open system technologies but very few are accepted in practice.	Enersip; BEST Energy; BeyWatch; eDIANA.	Need of diagnostic methods to control devices; Systems predicting future consumptions are not yet available.	Embedded diagnostic methods to allow early detection of anomalous energy consumption; Introduction of Load management algorithms.
1.3 Interoperability and standards			
It seems clear how IPv6 technology will enable the integration of various subsystems within buildings.	HOBNET	Extensive protocols and standardised methods need to be introduced supporting interoperability.	Standardised data models and real-time communication protocols; Integration of devices sharing the same protocol to function together.
1.3 Knowledge sharing			
Migration from a knowledge sharing (first generation) to a knowledge nurturing (second generation) culture.	H-KNOW Project	Generation of a common platform for all stakeholder groups involved.	Shared knowledge databases; Use of inter-organisational knowledge platforms.

** Directly related projects were not identified this research-topic*

2.5.1 Process integration

The importance of collaboration between different design disciplines has been widely recognised by the building industry. Traditionally this is achieved through physical meetings between the representatives of different design groups. However, this is facing more challenges when dealing with large and complex design problems. Various approaches have been introduced to face this problem, such as multi-agent systems (MAS) and the multi-disciplinary design optimisation (MDO) approaches.Further research in applications that will allow the control of parallel processes done by different kinds of experts involved in a project is needed. Also it is important to take into account the development of smart workflows in this kind of applications due to the dynamic behaviour of these projects. New applications to give support to all these needs and will allow to different profiles of experts work together in a project. This kind of applications will offer smart workflows.

2.5.2 System integration

There are many system technologies available that claim to be an open system technology: each one has its peculiarity and standards, but only few of them have gained wide acceptance and application. However, they have very different network, software (communication protocols and configuration tools) and hardware requirements. With IPv6 protocol, in practice, it is possible to assess how an IP backbone is built and how other protocols are used at the (sub) system level. If each individual component would end an IP address this ultimately means that each of them needs dedicated supplement hardware at additional cost.

Embedded software and devices are needed to control the consumption of buildings using diagnostics methods to control the devices. Systems to predict future consumptions and plan them are also a wide field to be investigated. Embedded diagnostics methods, capable of running on local controller devices will be developed to allow for early detection of anomalous energy consumption and/or malfunction of individual components. Load management algorithms will consider future energy consumption.

2.5.3 Interoperability andstandards

In order to ease the interoperability and the communication among different devices, protocols to achieve it should be standardised. IPv6 technology seems that will allow this, but a big research in this area is already needed. The latter form the third generation of knowledge management and represents key challenges faced by modern organisations in the Architecture, Engineering and Construction (AEC) industry. This value creation is grounded in the appropriate combination of human networks, social capital, intellectual capital, and technology assets, facilitated by a culture of change.Data models and real-time communication protocols will be standardised in order to allow all the stakeholders to develop their devices without problems at the moment to plug them and make them to work together. All the devices inside and outside the buildings will share the same protocols.

2.5.4 Knowledge sharing

To be effective, organisations need not only to negotiate their migration from a knowledge sharing (first generation) to a knowledge nurturing (second generation) culture, but also to create sustained organisational and societal values. A common platform for all the stakeholders involved in this sector has to be developed in order to allow the sharing of knowledge among them and ease the search of information organised and effective.

All the knowledge of all stakeholders involved in construction and energy efficient buildings issues will be shared between them using inter-organisational knowledge platforms that will contain all the information organised by term and will offer an easy way to be consulted.

3 Prioritisation of research topics

This chapter is based on the two prioritisation workshops held in Genoa on July 4th and Brussels on July 12th 2011, and prioritisation templates received afterwards by e-mail. Together 78 prioritisation questionnaires were received by the time for this deliverable (Figure 1). Majority (33 out of 78) of the respondents were from research institutes, universities or research funding organisations. At this point no further interest areas were reported.

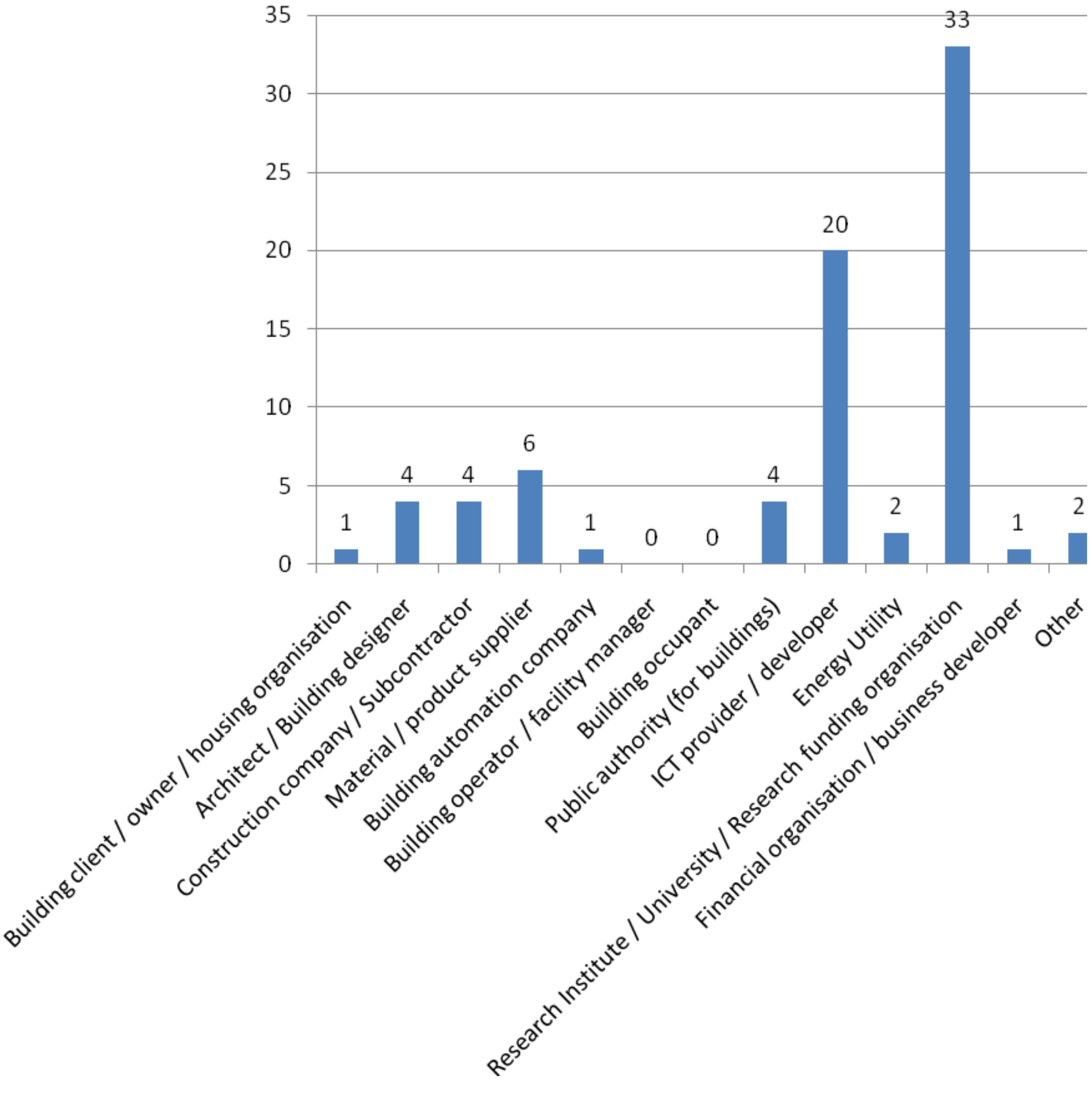

Figure 1: Amount of respondents in each stakeholder class

Taking into account the small number of responses received and in order to have more solid prioritisation of topics, the dissemination work will continue and prioritisation will continue in a form of a web-based questionnaire. The results will be embedded in the final roadmap (D2.4) on autumn 2012. The current responses are also somewhat biased due to the nature of the audience in the workshops. People tend to consider those items important they are working with at the moment. This on the other hand is a result of the financed research efforts in the past. In able to overcome this bias, the efforts to extend the basis of stakeholder groups will continue.

3.1 Prioritisation by stakeholder group

3.1.1 Designers, construction companies, material and product suppliers

Based on the prioritisation of experts identifying themselves as architects or building designers the most important research topics relate to the simulation, understanding ICT impacts, fun and easy interfaces, user centric design, building management systems, access to knowledge, simulation and interoperability. Research efforts on technologies related to contract and supply network management, performance metrics, commissioning, audits, labelling, demand response capabilities, smart grids and the built environment, groupware tools, distributed systems, and system integration should be included if possible.

From construction company's and subcontractor's point of view the user awareness and decision support issues like performance management, visualisation of energy use and behavioural change were considered the most important research topics.

Priorities from material and product suppliers vary a lot in relation to the area purpose of use of the products and systems. The most important areas, however, are linked to requirement definition and concept design, modelling, system concepts, improved diagnostics, understanding ICT impacts, and fun and easy interfaces. Design, performance estimation, and user awarenesswere considered important with a high rate of variability between the ranks.

Energy storage, as well as systems and products for renovation were identified as important categories.

3.1.2 System providers

It is important for system providers to prove the return of investment (ROI) of their products and services. Through the use of simulation based control design one could get estimates of energy savings. However this field needs further research to get reasonable accuracy with limited resources.

Another way to provide more attractive and cost effective solutions is through collaborative efforts. The work invested during the design and construction phase of a building is seldom reused in the operations phase. Efforts are needed in standardisation of data models and procedures to make this possible.

Increasing and variable energy prices are incentives for buildings to interact with the energy providers. The smart grid requires smart buildings that automatically adapt to the current availability of energy. This interaction needs to be standardised to ensure cost effective deployment and grid stability.

Wireless technologies shows promises of being costs effective while providing flexibility to changing buildings and needs. Development of communication protocols is needed to ensure interoperability between vendors and support for low power devices.

3.1.3 Users

The main need to make building occupants, building client and building owner aware on how their activities will influence energy use from short and long term perspectives is represented by the development of accessibility and usability intelligent visualisation system interfaces.

The interviewed stakeholders, that belong to building occupants, building client and building owner domain, have different behaviour, habits and different knowledge regarding computers and technologies, highlighted how the "visualisation of energy use" is the more rated subcategory of "User awareness and decision support" thematic area for which are required relevant modifications.

Despite different life-style or way to live the "energy life" in a building, the identified stakeholders pointed out the weakness of the current visual interface present on the market.

New generation of visual interfaces must be implemented in order to be easily accessible by the end user and at the same time should be able to provide data on real-time energy consumption and billing costs to user in an intuitive and attractive way.

With reference to the above consideration, visualisation of energy use will be ensured by using an internet accessible, smart, and usable interface, and also providing them useful suggestions to manage their habits to decrease energy consumption and billing costs.

3.1.4 Energy suppliers

The energy management and energy trading spawn various stakeholders. In the traditional scenarios these include energy providers, facility management providers etc., however in the smart grid era, especially the energy trading stakeholders are significantly expanded since now anyone (building manager, company facility manager etc.) can participate in trading. The initial workshops held depicted the trend towards high-priority issues for energy trading and management.

In building and district management priority is given to forecasting and new approaches in management of energy, as it is assumed that existing building management systems and smart metering infrastructure exist. Integrating smart devices is also seen as key part for the longer term. In smart grid and the built environment, priority is given on demand-response capabilities and load balancing in the short term, while integrated network design, and secure communication will emerge in the mid or longer term. Finally all agree that standardisation is a high-priority issue in order to avoid isolated solutions; however it is also seen as a major challenge also. Similarly management for distributed storages and their prompt integration with demand-response techniques as well as energy marketplaces is also seen as important.

We have here to point out that energy management and trading put in the smart grid era are much wider in scope and challenges and spawn multiple stakeholders. Hence it is quite challenging to really isolate single priorities in an infrastructure envisioned to be collaborative and highly interconnected.

3.1.5 ICT service providers

As we have seen in previous deliverables in this project, one of the areas where lots of investments are being made and where currently exists lots of on-going research is the area of integration technologies.

Within this large segment that includes heterogeneous categories such as Integration Process, System integration, Knowledge sharing and Interoperability and standards, perhaps the most interesting and important for stakeholders is the last one.

Stakeholders assume that wide adoption of IPv6 protocol will help a lot in the research of a common protocol to be used by most of vendors as already pointed out by the IPSO Alliance (www.ipso-alliance.org) [7]. It would be really useful for the development of new devices that can be connected inside and outside the buildings sharing the same protocols.

Nowadays, regarding systems integration, each company or vendor uses their own technology depending on their know-how or expertise.

This situation produce that a wide variety of different technologies are coexisting making really tough the integration of them and makes difficult to combine devices of different companies. We can easily conclude that it's necessary to obtain and develop a standard interoperable for all vendors.

Another important lack in this area considered important by stakeholders is related to knowledge sharing between stakeholders involved in energy efficient buildings.

It is necessary an improvement of seek methods in a common platform to allow a good access to huge amount of information related to all kind of fields involved in e2b from all stakeholders to push forward the research in this field.

Regarding process integration, most of stakeholders consider it not very important due to the important extra-work documenting that implies to do between very different roles that they consider not necessary.

3.2 Prioritisation by category

Following tables indicate the distribution of prioritisation for each research topic. Building and district modelling, and simulation got the greatest amount of “MUST have this as soon as possible” –responses indicating the short term priority of these subjects. On the other hand, onsite and off-site production management and procurement were seen research topics relevant in the long term (NOT now but maybe in the future -responses). See following Figure 2about the distribution of the values.

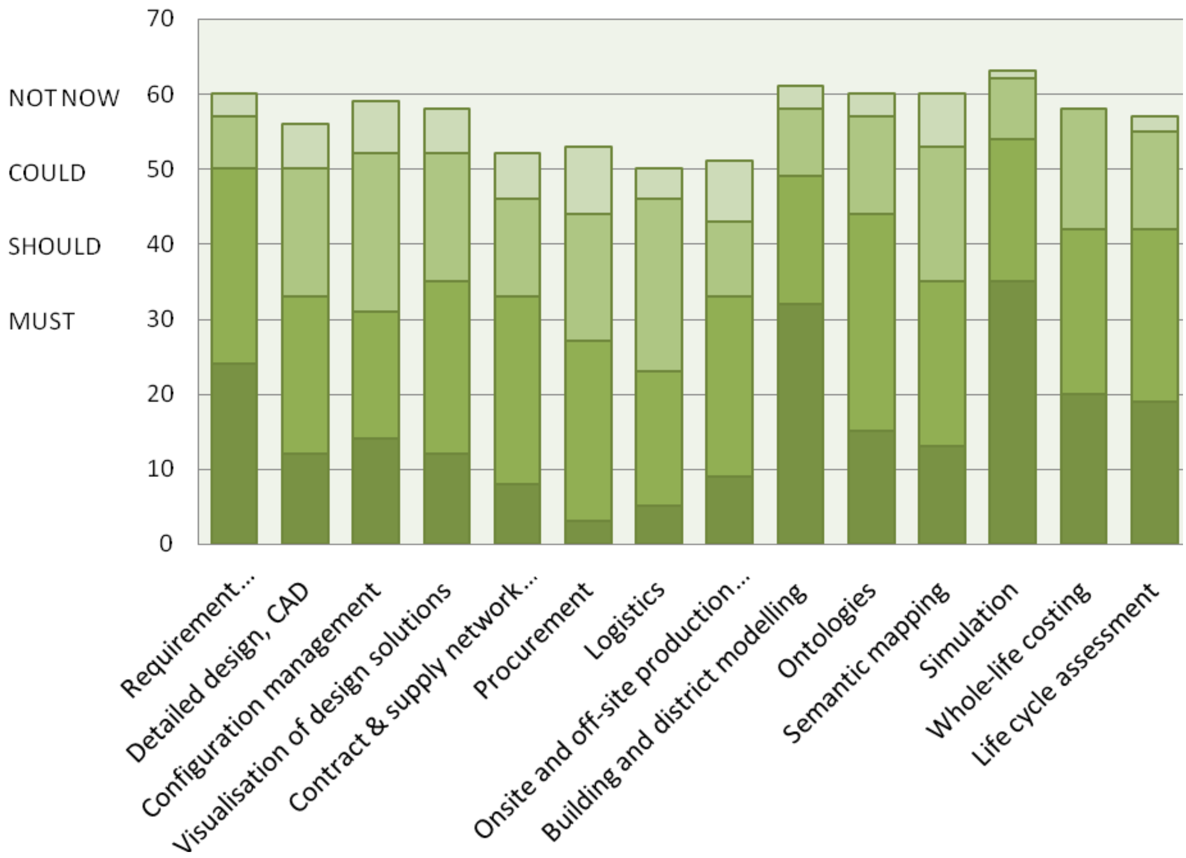

Figure 2:Tools for integrated design and production

Production management sub-category (contract & supply network management, procurement, logistics, and onsite and off-site production management topics) were seen least relevant among the respondents, however, our feel is that this was affected by the bias of respondents mentioned earlier. Following topics arose in the responses as other topics overlapping heavily with the category Interoperability:

- Data structure and access framework
- Mass customization for retrofitting
- Model Interoperability

- CAD Interoperability
- Decision tool to surface best scenarios for investing in EE
- Model Interdisciplinary

Following Figure 3represents the priorities among Intelligent and integrated control-category. Smart metering was seen as the most important in the short term, whereas secure communications was considered relevant in the long run.

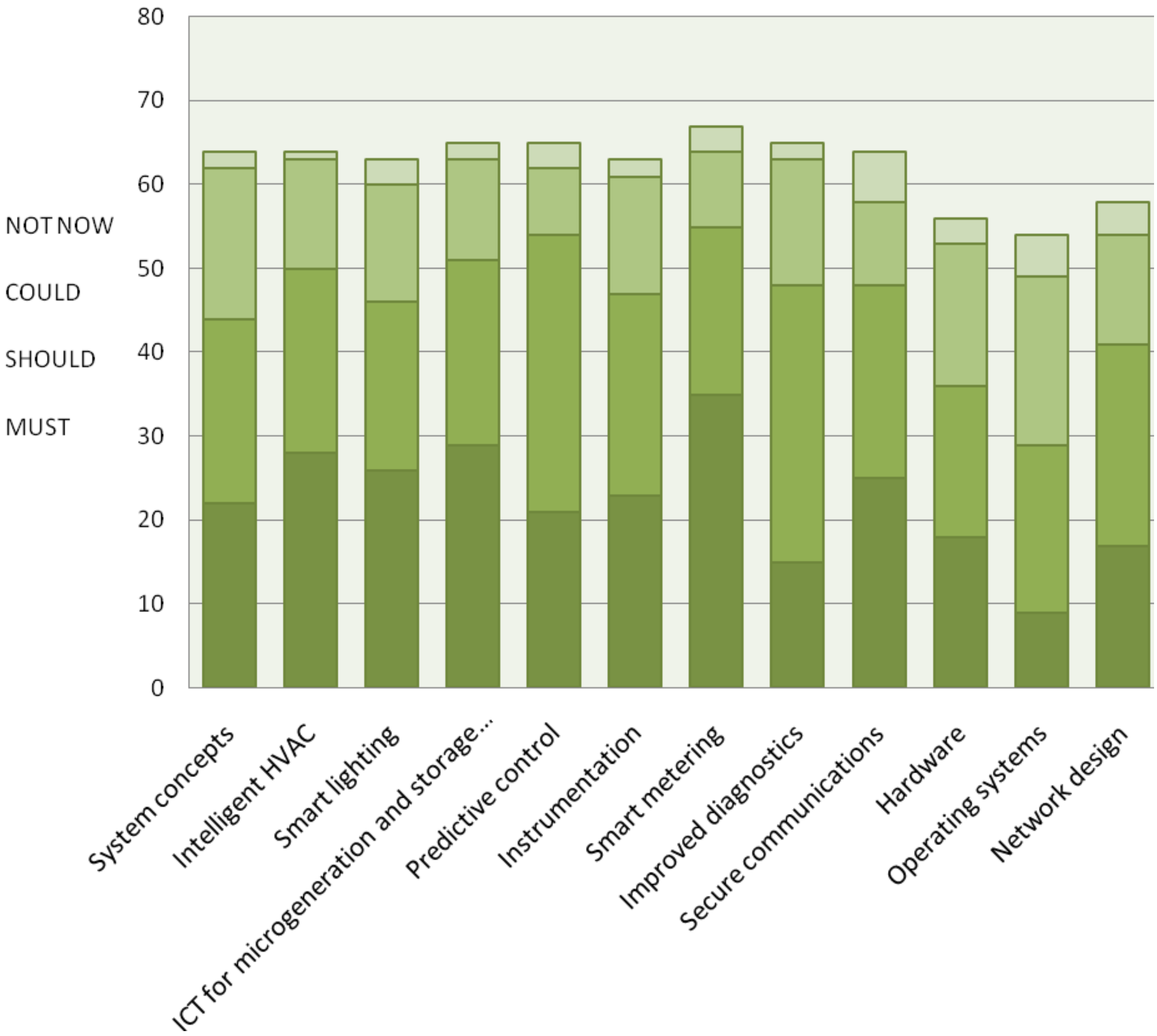

Figure 3:Intelligent and integrated control

Topics under the sub-category Wireless sensory network (hardware, operating systems, and network design) were considered least relevant in relation to category Intelligent and integrated control. Operating systems were seen somewhat relevant in the long term. Some new topics were identified as other and considered as 'MUST' by the respondents:

- Autonomous WSN (energy harvesting)
- Complex data communication management
- Sensor for air and comfort

- Wireless sensory network (WSN) Interoperability
- User centre building controls
- Optimization of the interaction between EE subsystems
- Building system integration

In the category of User awareness and decision support, the most important short term research topic would relate to the performance analysis and evaluation, and user centric design. Social Media was seen not relevant at the moment, but something to be considered in the long run.

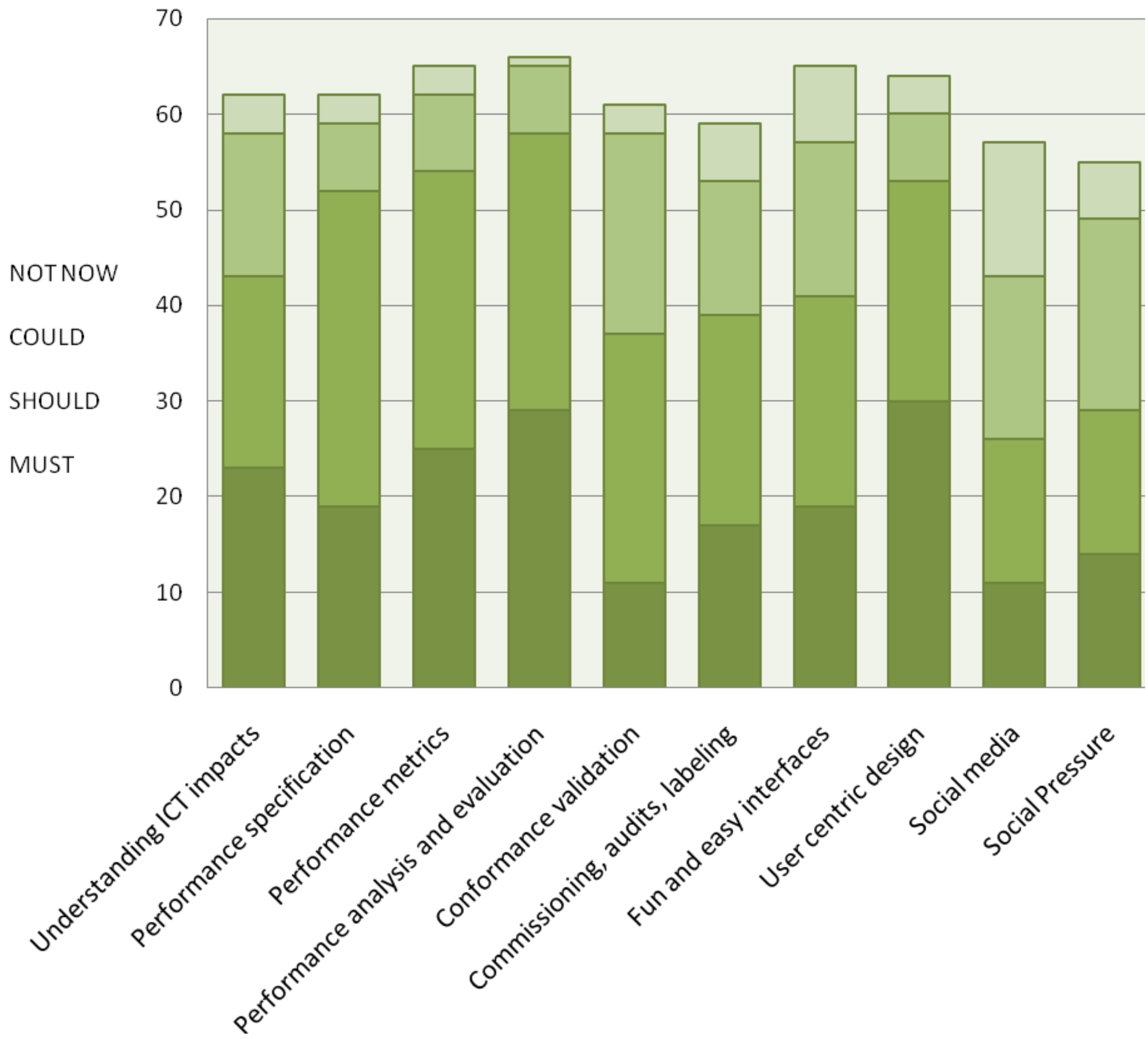

Figure 4: User awareness and decision support

Following topics were identified in the others section and considered as 'MUST':

- Ambient assistant living
- Education and training
- Communication supplier client-government

Energy management was considered in the previous deliverables as one of the key areas for research. These results indicate that building management systems must be among the top priorities in the near future. None of the research topics were considered relevant in the long term.

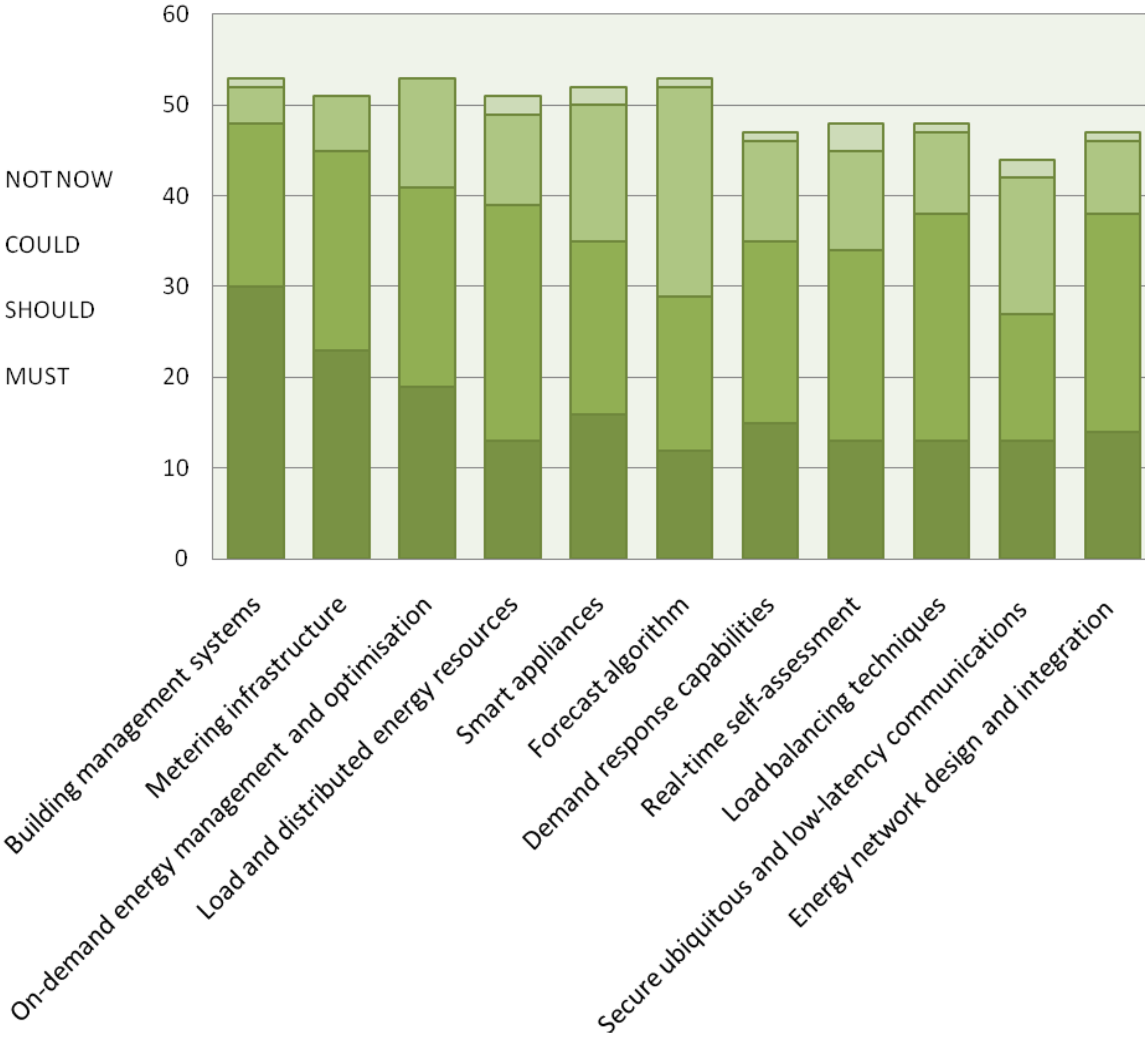

Figure 5: Energy management and trading

Following topics were identified in the others section and considered as ‘MUST’:

- Storage
- Standardisation
- Energy management for distributed storages
- DC/DC NET
- ICT for micro grids concepts (electronic energy markets)
- Energy usage – renovations
- Solutions for energy efficient building renovations
- Business models for energy efficient building renovations

Solutions of integration technologies are a key to many current challenges. The most relevant short term topic would deal with the access to knowledge. Electronic conferencing and cabling were seen more relevant in the long term. However cabling 32 out of 78 respondents did not consider this topic relevant at all.

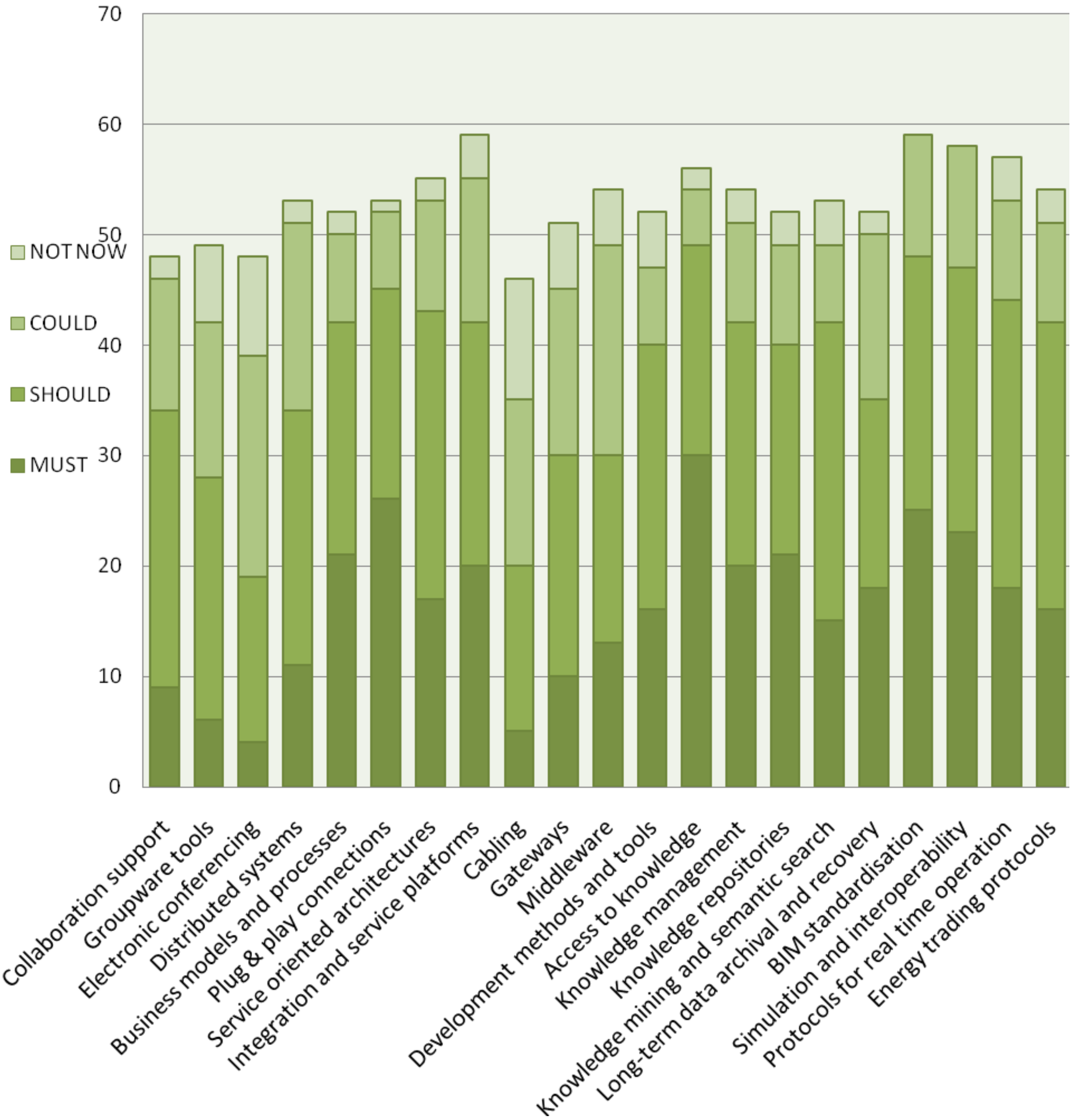

Figure 6:Integration technologies

Many topics relating to the integration technologies and interoperability were already identified as important in other categories. Following topics were identified in the others section and considered as 'MUST' or 'SHOULD':

- Geo reference data
- Long life time ICT packages module
- Local storage package (security)

4 Main findings

Stakeholder group	MUST	SHOULD	COULD	NOT NOW
Designers, construction companies, and material and product suppliers	(>4 answers) Performance estimation; Interoperability and standards (sub-categories) Requirement definition concept design; User centric design; Access to knowledge (topics)	(>5 answers) Tools for integrated design and production (category) Modelling; Monitoring; System integration (sub-categories) Performance metrics; Performance analysis and evaluation; Commissioning, audits, labelling; Energy network design and integration; Service oriented architectures; Integration and service platforms (topics)	(>4 answers) Quality of service (sub-category) Logistics; Forecast algorithm (topics)	(>3 answers) Procurement, Social media (topic)
System providers (<5 respondents)	N/A	N/A	N/A	N/A
Users (<5 respondents)	N/A	N/A	N/A	N/A
Energy suppliers (<5 respondents)	N/A	N/A	N/A	N/A
ICT service providers	(>7 answers) Interoperability and standards (sub-category) Simulation; Smart metering; Demand response capabilities (topics)	(>7 answers) Modelling; Automation and control; Building and district energy management; Knowledge sharing (sub-category) Predictive control; Load and distributed energy resources; Plug & play connections; Protocols for real time operations (topics)	(>5 answers) System concepts; Social pressure (topic)	(>3 answers) Semantic mapping (topic)

There were considerable amount of variation inside the each stakeholder groups. Each partner analysed stakeholder specific data and complemented their earlier analysis with it.The most widely considered research topics (more than one third of respondents considered as MUSTs) that must be advanced as soon as possible were:

- Building and district modelling
- Simulation
- Intelligent HVAC
- Smart lighting
- ICT for microgeneration and storage systems
- Smart metering
- Performance analysis and evaluation
- User centric design
- Building management systems
- Plug & play connections
- Access to knowledge

The data collected so far for this research was biased and the dissemination work needs to continue in able to get results that more fundamental conclusions can be drawn.

5 Acronyms and terms

AEC	Architecture, Engineering and Construction sector
BAS	Building Automation System
BIM	Building Information Modelling
BMS	Building Management System
BPIM	Building Performance Information Management
CAD	Computer Aided Design
CFL	Compact florescent light
Cloud technology	The use of additional computing power over Internet
CO_2	carbon dioxide
Dashboard	Instrument panel, operating table, switch desk
DoW	Description of Work
DR	Demand Response Side Manager
DSO	Distribution System Operator
EE	Energy Efficiency
GIS	Geographical Information System
HVAC	Heating, Ventilation, and Air Conditioning systems
ICT	Information and Communication Technologies
ICT4E2B	Information and Communication Technologies for Energy Efficient Buildings
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCM	Life Cycle Management
LED	Light emitting diode
MAS	Multi-Agent Systems
MDO	Multi-disciplinary Design Optimisation
MEP	Mechanical Electrical and Plumbing works
PC	Personal Computer
Prosumer	PROducer and conSUMER
REEB	European Strategic Research Roadmap to ICT enabled Energy-Efficiency in Buildings & Construction
RFBT	Radio Frequency Based Technology
ROI	Return of Investment
RTD	Research and Technology Development
SME	Small and Medium Enterprises
TV	television
WSN	Wireless Sensor Networks

6 References

[1] Hannus, Matti; Kazi, Abdul Samad; and Zarli, Alain, Eds. *ICT Supported Energy Efficiency in Construction - Strategic Research Roadmap and Implementation Recommendations*, 2010 REEB Project Consortium

[2] EeB - The Ad-hoc Industrial Advisory Group, *Energy-Efficient Buildings. Multi-Annual Roadmap And Longer Term Strategy*, 2010

(http://www.ectp.org/groupes2/params/ectp/download_files/36D1191v1_EeB_Roadmap.pdf)

[3] ICT4E2B Forum, Deliverable 1.2, Initial analysis of the state-of-the-art

[4] ICT4E2B Forum, Deliverable 1.3, Initial analysis of research projects

[5] ICT4E2B Forum, Deliverable 2.1, Application scenarios

[6] A Guide to the Business Analysis Body of Knowledge® (BABOK® Guide), 2009, International Institute of Business Analysis, Version 2.0

[7] Karnouskos, Stamatis; Vasseur, Jean-Philippe;Wetterwald, Patrick;Martocci, Jerald P.;Humpal, Ted and Zhu, Ming. The Internet of Things and the convergence of networks.RTC magazine, November 2010.http://rtcmagazine.com/articles/view/101879