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 D2.3: Draft research roadmap

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SEVENTH FRAMEWORK PROGRAMME

Executive summary

The ICT 4 E2B Forum project intends to promote, 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 developers as regards the use of ICT to support informed decision-making (both human and automated) in the current delivery and use of sustainable and energy-efficient buildings and districts.

The work is majorly based on the results obtained from the previous deliverables of application scenarios (D2.1), prioritised gaps (D2.2) and findings from the REEB project. The intention was to update the existing REEB roadmap [1], consisting of Vision, Strategic Research Agenda (SRA) and Implementation Activity Plan. The SRA is developed within the five thematic areas. Vision, key research topics, drivers, barriers and impacts were developed to each of these thematic areas. In addition, the document includes the synergies of the ICT4E2B forum project with existing roadmaps EeB PPP Multi-annual roadmap followed by Updated Vision and SRA.

The ICT 4 E2B Forum vision for ICT supported energy efficiency of buildings in the short, medium, and long term is displayed in Figure 1:

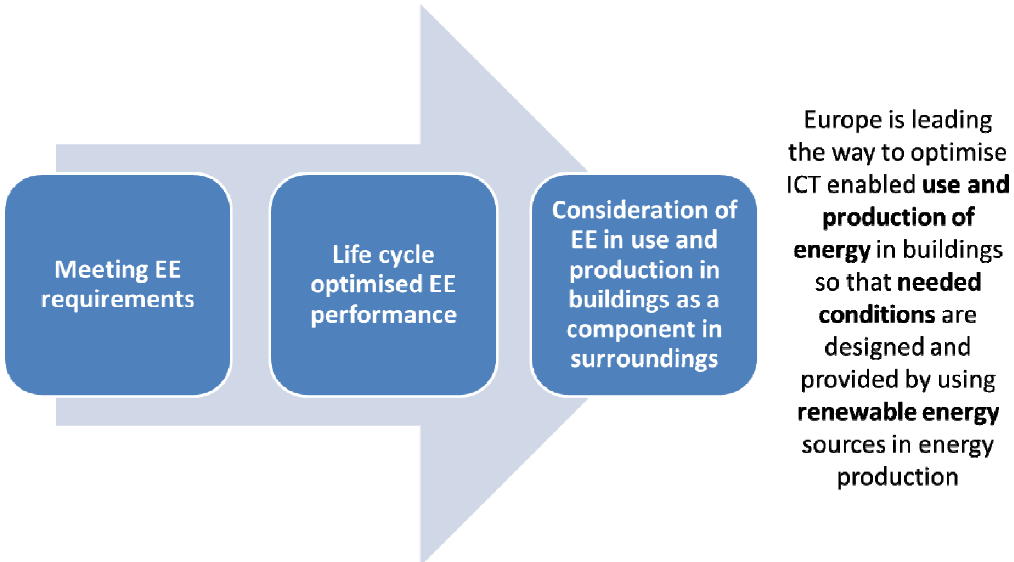

Figure 1: Updated vision for ICT enabled energy efficiency in short, medium and long term (cf. REEB [1])

Table 1resumes the main ICT4E2B foresighted vision for each thematic area and the categories in each of these areas.

Thematic area	Vision
EE design and production management	Integration of various functions, tools and communication between stakeholders; Contractual practices including valid verification of EE; Self-learning/adapting design system; Validation and certification of simulation software tools; Contracts/solutions based on models and life cycle EE performance.
Intelligent control	Collaborating subsystems and optimal predictive control; Collaborating buildings on district/neighbourhood and city-wide level interaction with the smart grid; Self-diagnostics systems with high degree of monitoring while guaranteeing security and respectingprivacy; Building controls are derived and tuned based on dynamic building models that through simulation show the nominal energy consumption.
User awareness and decision support	There are available tools/applications, which exploit real time energy consumption information and help the different stakeholder to define the level of efficiency of the building. Visualisation of energy use will be ensured by using Internet-enabled, smart, and usable interfaces e.g. smartphones, and intelligent applications which provide useful suggestions to change habits to adjustenergy consumption and costs.
Energy management and trading	Flexible building energy management adjustable to user's as well as external needs; Integration of intelligent devices and accurate forecasting by context information integration; Interoperable energy management solutions beyond standalone systems/buildings; Real-time energy management depending on Key Performance Indicators; Real-time Demand-Response depending on local resource availability; Buildings should collaborate with the local district for energy efficiency; Collaboration of buildings with each-other; Collaboration with the smart grid markets
Integration technologies	Parallel processes, smooth and smart workflow and tight control; New applications to support all these needs allowing different experts work together in a project; Early detection of anomalous energy consumption and/or malfunction of individual components by using embedded diagnostics methods, which are capable of running on local controller devices; Standardised data models and real-time communication protocols are allowing all the stakeholders to develop their devices without problems of interoperability; Knowledge of all stakeholders involved in construction and energy efficient buildings issues will be shared between them using inter-organisational knowledge platforms that contain all the information organised by term and will offer an easy way to be consulted.

Table 1: Visions by thematic areas

Previous work conducted in REEB and EeB provided a solid ground for the research roadmap presented in this document. New technologies were not identified; however the developments in interoperability and standardisation might lead to the consolidation of existing technologies. An increasing focuses and overall change to user-centric and district level solutions can be seen.

The results will suggest the updated Implementation action plan for research, standardisation, education, actions for industry (Construction sector, ICT sector, and energy sector), policies and regulations. These final updated recommendations will be developed on the upcoming project deliverable D2.4, after stakeholder's feedback on the draft roadmap presented in this document.

The Final Research Roadmap will define objectives and timeframe for future research topics and activities: multi-disciplinary research, demonstrations, dissemination, best practice promotion, education and training, innovation policies, standardisation etc.

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1 Introduction

Purpose

The objective of this document is to present the draft research roadmap consisting of five distinctive roadmaps based on prior division of thematic areas followed from REEB project (refer section 1.3). This work is majorly based on results obtained from the previous deliverables of future application scenarios (D2.1), Prioritised gaps (D2.2) and findings from the REEB project [1].

Furthermore, the document includes the synergies of the ICT4E2B Forum project with Energy-efficient Buildings (EeB) PPP Multi-annual Roadmap [2], preliminary suggestions for the updated Implementation action plan for research, standardisation, and education, as well as actions for industry (construction sector, ICT sector, and energy sector), policies and regulations.

Document structure

The document is structured in the following sections:

- Section 1: Introduction presents the purpose and general background of the deliverable D2.3 Draft research roadmap.
- Section 2: Elaborates the synergies of ICT4E2B Forum project with existing EeB PPP Multi-annual Roadmap.
- Section 3: Represents consolidated vision.
- Section 4: Details the updated strategic research agenda.
- Section 5: Outlines suggestions for the updated implementation plan.
- Section 6: Conclusions focuses on the description of next steps and the main findings followed by acronyms and terms and references

Baseline

The main inputs at the start of the work were:

- Existing roadmap on ICT contributions to improve energy efficiency of buildings by REEB project was used as baseline for ICT4E2B forum project. [1]
- EeB PPP Multi-annual Roadmap and Longer Term Strategy. [2]
- Previous deliverables from ICT4E2B Forum
  - D1.1 Classified research areas [3]
  - D1.2 Initial analysis of the state-of-the-art [4]
  - D1.3 Initial Analysis of research projects [5]
  - D2.1 Application Scenarios [6]
  - D2.2 Prioritised Gaps [7]

Methodology

This document is an update for the existing REEB roadmap [1], consisting of Vision, Strategic Research Agenda (SRA) and suggestions for implementation activities. The SRA consists of prior division of five distinct thematic areas, each divided into vision, key research topics, drivers, barriers and impacts.

The roadmap template provided by VTT is divided into research priorities of short term, medium term and long term where the drivers, barriers and impacts are related to transition between short-medium-long terms as following:

- Driver: Why would one want to move to the next level?
- Barrier: What prevents one from moving to the next level?
- Impact: What are the benefits from moving to the next level?

A web questionnaire was developed and is open as used in deliverable D2.2 Prioritised gaps, the research and technology development (RTD) prioritisation process will be continued and results obtained from industry experts and stakeholder groups will be included in D2.4 Final research roadmap.

Partners (VTT, Schneider, D'Appolonia, SAP and Atos) used the baseline information, results obtained from previous deliverables and REEB roadmap [1] to derive the updated SRA.

Furthermore the upcoming deliverable (D2.4) will provide the following:

- The initial version of the roadmap will be presented at the validation workshop with the experts group for feedback on contents and priorities.
- The objectives and timeframe for future research topics and activities: multi-disciplinary research, demonstrations, dissemination, best practice promotion, education and training, innovation policies, standardisation etc.

2 Synergy with EeB PPP Multi-annual Roadmap

The Energy-efficient Buildings (EeB) PPP, launched under the European Economic Recovery Plan [8], will devote approximately € 1 billion in the period 2010-2013 to address the challenges that the European construction sector and its extended value chain are facing in their ambitious goal of researching new methods and technologies to reduce the energy footprint and CO_2 emissions related to new and renovated buildings. This represents the initial and highly strategic step of a longer term set by the industry to create more efficient districts and cities while improving the quality of life of European citizens.

Within this framework the Energy Efficient Building Association (E2BA) [9], in its role of industrial interlocutor of the European Commission in the EeB PPP, and in particular the Ad-hoc Industrial Advisory Group (AIAG) has developed a multi-annual roadmap with the objective of identifying the main research priorities for industrial stakeholders and to define a long term strategy in the framework of energy efficient building technological area.

The methodology for EeB Roadmap development used by the AIAG has been based on the broad consultation of E2BA members and the enlarged network of stakeholders. In fact through the E2BA members and their multiplying effect, a large community of local authorities, capital providers, developers (designers, engineers, contractors), supply chain (materials and equipment suppliers), investors and owners as well as end users have been reached, providing a broad overview of the research needs for the future of the sector. Indeed, over 200 contributions highlighting research challenges and opportunities have been gathered from more than 100 E2BA member organisations, organised in five working groups. It is very important to underline that this stakeholder-based approach has been taken as reference and baseline for the ICT4E2B Forum approach, where this large-based approach has been further extended with the “Forum” concept that should continuously involve stakeholders in roadmap development. Furthermore it is worth to notice that 4 of the 6 partners of this project are members of E2BA, which allows the project to exploit the already mentioned multiplying effect of the association.

During EeB Roadmap preparation, an in-depth analysis of strategic research agendas, implementation plans and relevant R&D position papers from running European Technology Platforms (ETPs) and Joint Technology Initiatives (JTIs) was performed in parallel. This was duly confronted with other relevant European initiatives, such as the roadmaps of the industrial initiatives or the SETIS information system within the SET Plan. This allowed the building up of a taxonomy, which globally maps the European R&D priorities landscape, relevant to energy-efficient buildings. In case of ICT4E2B Forum the main input for the taxonomy has been the one delivered by REEB that has been further investigate and refined during the project, nevertheless it is worth to notice that the main thematic areas of ICT4E2B and REEB can be easily resembled in EeB PPP taxonomy.

The two parallel exercises performed by E2BA demonstrated a powerful synergy and have been very important in the identification of research priorities. More than 1700 inputs from relevant European initiatives of potential interest for energy-efficient buildings have been identified. The inputs collected from the E2BA members have been compared with research priorities identified from the analysis of the strategic research agendas, implementation plans and relevant R&D position papers, as a crosscheck that relevant research challenges for the sector were not missed. An in-depth analysis and clustering exercise has been performed on the research gaps and challenges gathered during this initial phase. Five major areas have been identified, each grouping several research challenges (see figure below).

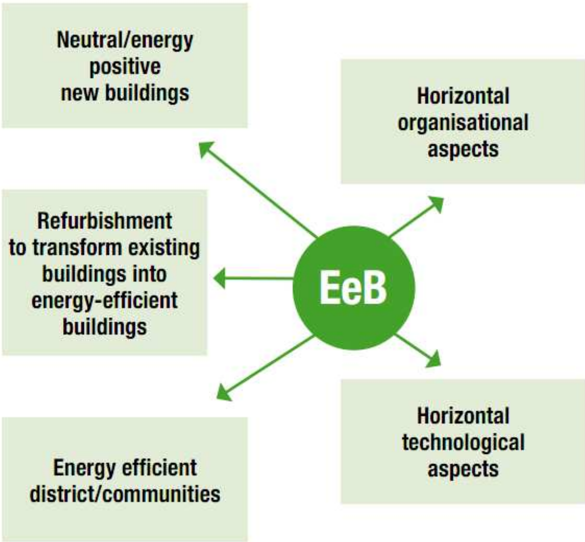

Figure 2: EeB PPP Multi-annual Roadmap

All the five areas can be influenced by development of ad-hoc ICT, which could effectively contribute to the advancement of the energy-efficient built environment. At the same time with the development process of the new Framework Programme (FP), E2BA is going to start two relevant road-mapping exercises that can take relevant contribution from the outcomes of ICT4E2B Forum:

1. Update of the PPP Multi-annual Roadmap, E2BA is going to accurately reconsider the different prioritised challenges under the 5 main areas. This update work will be influenced by the activities performed by running project and by the new priorities underlined by stakeholders. ICT4E2B Forum will be able to contribute by the detailed analysis of running activities performed in D1.3, while prioritisation performed in D2.2 will allow giving the perspective of ICT4E2B stakeholders.
2. Development of New Long Term Strategic Roadmap, to really adapt the E2BA long term strategy at the general socio-economic evolution and to the specific need of the upcoming Framework Programme, it seems necessary the development of new long term strategic roadmap with a clear perspective of what the field of energy-efficient buildings can achieve at different timescale. Within this activity ICT4E2B Forum roadmap (D2.3 and D2.4) will be able to give a clear understanding of what are the vision, gaps and priorities and all ICT4E2B relevant challenges.

3 Updated vision

“ICT will contribute to the energy efficiency of buildings mainly via design tools, automation and control systems and decision support for various stakeholders” REEB [1]. Following Figure 3 represents the vision generated in the previous REEB project.

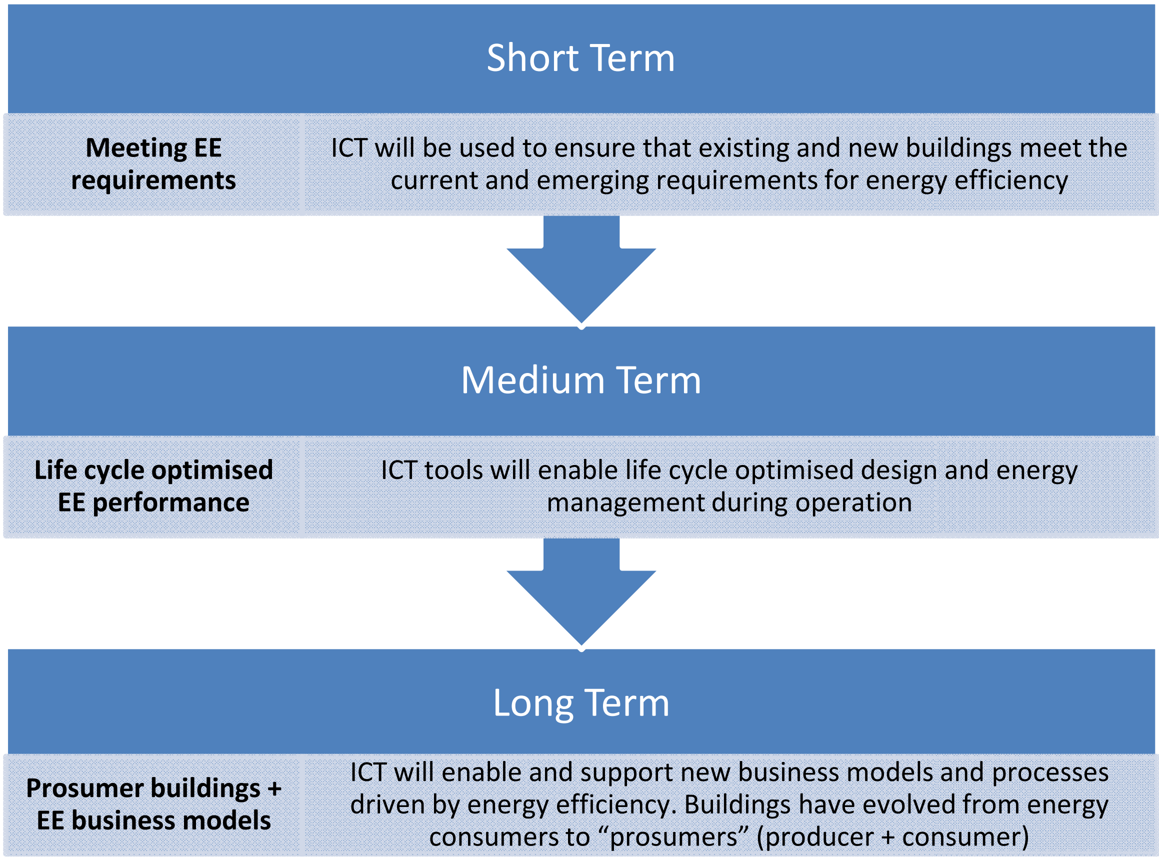

Figure 3: Vision of ICT enabled energy efficiency in short, medium and long term (REEB [1])

EeB roadmap team identified following three key pillars in able to form the needed more holistic understanding about the issue [2]:

1) Systemic approach considering
    - technology integration;
    - integration of renewable energy to energy grids;
    - retrofitting to existing building stock, and
    - involvement of individuals
2) Extension from building level to group of buildings and district levels
3) Extension to “geo-clusters”
    - similarities connecting trans-national areas/markets

Following updated vision is an extension of the work conducted in REEB [1] with EeB [2]. It describes the state of development for ICT enabled EE in buildings in Europe after 10 years divided into short, medium and long term steps:

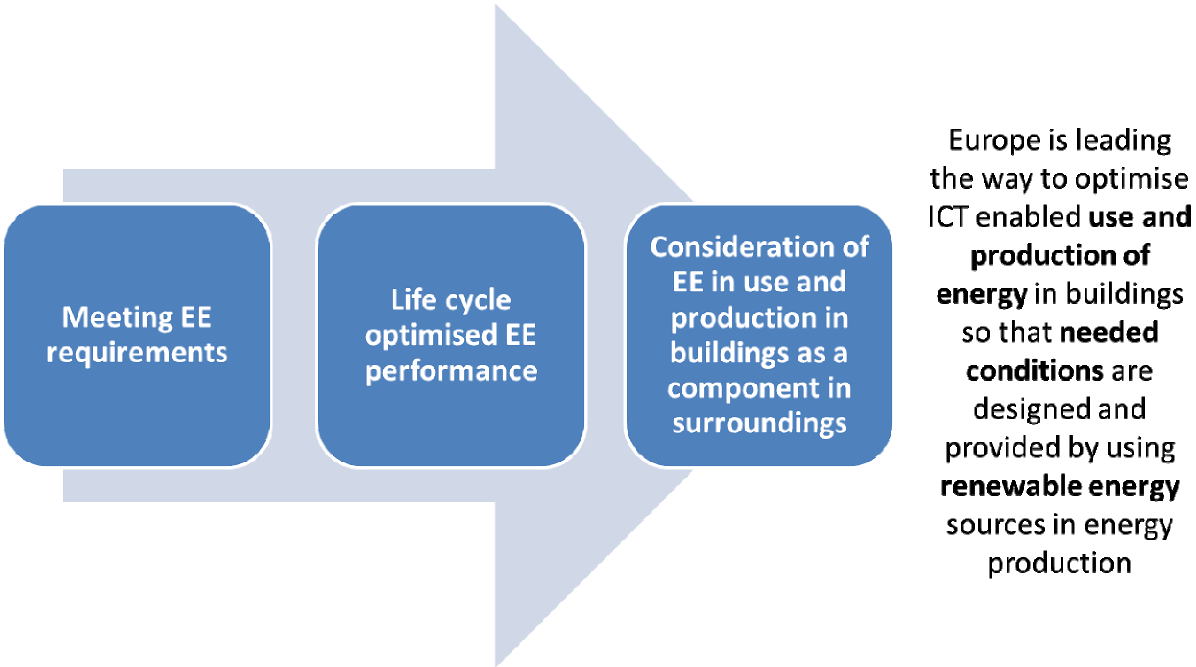

Figure 4: Updated vision for ICT enabled energy efficiency in short, medium and long term

Short term	
Meeting EE requirements	ICT enables the connectivity and interoperability of individual buildings and networks and will be used to ensure that existing and new buildings meet the current and emerging requirements for energy efficiency defined in relation to the surrounding infrastructure and climate.
Medium term	
Life cycle optimised EE performance	Design, production, retrofitting, use and demolition are empowered and enabled by re-configuration, optimisation, and access to real-time information, decision support tools and interoperability in easy to use interfaces.
Long term	
Consideration of EE in use and production in buildings as a component in surroundings	ICT enables and supports renewal of business and processes driven by energy efficiency. Buildings have evolved from energy consumers to “prosumers” (producer + consumer).

4 Updated Strategic Research Agenda (SRA)

4.1 Tools for EE design and production management

4.1.1 Vision

BIM-CAD, Collaborative design environments, user interfaces

The architects and engineers are provided with libraries of intelligent (parametric) objects that can adopt (design / configure) themselves in a specific context with essentially less human interference than today. Transformation of design process from computer assisted manual work into a knowledge based “industrialised” process.

Best-practices will be embedded in BIM models as reference design solutions where built-in “smart advisors” will analyse or simulate the evolving BIM during the design process presenting various EE indicators as optimal solutions associated to the current design activity, instrumenting EE performance estimation as coherent feature of preliminary design phase.

Intelligent product catalogues with auto-design BIM software are available to choose producer independent materials from embedded EE-product catalogues. Intelligent (parametric) objects in libraries can adopt (design / configure) themselves in a specific context with essentially less human interference than today. There exists protection of the intellectual property rights (IPR)of design knowledge that is shared digitally with other organisations.

Semi-automatic generation of production plans by combining BIM with libraries of productions methods and resources (materials, components, machinery and suppliers) is available. Self-learning design system with embedded case-based learning is used. Integration of building and district level models include energy exchange between buildings, local generation, storage and grids.

Model analysis and validation, 3D-Visualisation

The decision making of owner/user is supported by exploiting virtual environments where simulation, visualisation, interaction and mixed reality with text, diagrams, 3D and comparison with EE indicators derived from BIM, will be used to evaluate entire life cycle cost of building supporting the interest of stakeholders.

Systems and service integration at all levels throughout the building life cycle enable collaboration of distributed teams. Versatile model analysis tools will be available for analyses and validation of BIMs, alerting users to take corrective actions e.g. with respect to coherency, EE and compliance to requirements and building codes.

Most commonly used building simulation tools will be fully interoperable with commercial design tools and BIM. Also full scale building simulation will take less amount of time where several alternative solutions can be studied rather quickly and easily. Test cases by comparing software tools in standardised reference cases will be used to develop validation/ certification process of tools.

Standardise performance indicators at European level will be available where they can be assessed based on standardised BIM and building energy management systems(BEMS) data which is available from various enterprise systems.

EE Verification, performance based contractual practices:

Project management interface will provide integrated context-oriented information for on-site and off-site construction management; implementation of ICT on remote construction projects will be commonly used for managing workflows and process flows.

Production will be managed through enhanced BIM-based tools with features to include output of optimised operations to improve energy efficiency. These include the logistics optimisation to reduce emissions and the purchasing of sustainable materials.

Quantifying tools for measuring EE and production management will be available with product database specifying the energy value of materials and logistics. There is real time collaboration between stakeholders for design, production management and building operation phase.

There are tools to specify the performance of the building and to verify it with respect to requirements. Monitoring is based on the real (future) building and analysis or simulation using BIM. Such tools will support performance-based contracts. The vision is to accept computer based analysis as contractually valid verification of EE.

4.1.2 Key research topics

Following presents some of the identified research topics in four categories:

Design

- Development of libraries of best practices and reference design solutions
- Certification of tools
- Development of contractual and legal validity of BIM, and digital information in general, as the carrier of design information without the need for "documents" like text and drawings (~"BIM-PDF")
- Development of tools supporting design and service configuration management
- Production management
- Development of tools to support collaborative working environments, modelling, simulation, social media, visualisation, workflow management
- Development of BIM-based project management tools, performance simulation, e-procurement, intelligent e-catalogues, ICT standards
- Development of tools to optimise production EE as part of life cycle (e.g. on/off-site production, local procurement, waste management)
- Enhancement of service provider/facilitator implementation of user requirements, service solutions based on integrated information models

Modelling

- Modelling interactions (energy trading transactions) between buildings and smart electricity and heating/cooling grids
- Development of tools to model analysis and validation for EE. Two kinds of validation is required
  (1) Ontology e.g. check that different stakeholders/tools have the same definition of the needed information about e.g. windows
  (2) Instantiated data e.g. check if a specific building, based on its model, complies with requirements e.g. EE
- Development of tools to support modelling of user behaviour with respect to energy consumption for design phase
- Enhancement of current BIM models (IFC) with standardised EE attributes
- Development of information models for mobile technologies

Performance estimation

- Definition of EE performance indicators and related assessment methods and tools
- Standardisation of performance indicators at European level in a way that they can be assessed based on standardised BIM and BEMS data which is available from various enterprise systems
- Development of tools to show overall performance of the building throughout life cycle and financial instrument to support stakeholders in evaluating the total cost and benefits
- Establishing estimated performance as contractually valid requirement and defining related verification methods
- Development of test cases for simulation software tools to support validation and certification
- Establishing virtual testing environment for Performance Estimation
- Development of performance verification tools /performance -driven process

4.1.3 Drivers, barriers and impacts

General expectation today is short term, i.e. fulfilling the requirements at lowest possible cost. A trend for stakeholder group is needed towards a longer term strategy for life cycle optimised buildings. Industry might gain more control, but energy efficiency factor needs to become the part of core strategy of business changing business models. In the current scenario companies need to provide added value to clients (e.g. EE services), thus not only changing the business models but by having other business in parallel differentiated by brand.

Regulation for energy efficiency centres will enhance on the regulation, directives, building codes, building permissions etc. The importance of integration of renewable energy sources increases and advanced stakeholders will support integration of building life cycle in operation phase as a longer-term strategy.

New applications will be driven by increasing EE awareness and new EE business models and services, and will mostly be enabled by integration of various functions/tools and improved communications between stakeholders.

As a barriers in the current scenario, for buildings to be energy efficient requires more efforts from the architects and designer where supporting tools for designing embedded with EE features and simulations consumes excessive amount of time and resources. There is a need to enhance such tools in a way that more results for designing and evaluation purposes in less time and with resources can be realized. Following are the identified barriers:

- Lack of interoperability
- Stakeholder specific sub-optimisation and inability to integrate model based information between stakeholders supported by the current regulations (e.g. tendering procedures)
- Unresolved IPR of semantically rich information
- Un-availability of EE data about materials and products
- No systematic feedback from operation to design
- Lack of rewarding contract models that support holistic optimisation; Incompatibility of business incentives for design vs. whole life cycle performance. No systematic feedback from operation to design

- Commonly used design simulation tools are not 100% interoperable with design tools leading to duplication of work and also require excessive time for full scale building simulation
- Prevailing business models are focusing on delivery costs instead of value to client
- Inability to measure, verify and prove EE of buildings
- Inability to integrate model based information between stakeholders

Gained impacts are:

- Compliance at lowest cost
- EE services (performance based contracts providing incentives for both sides, participation of stakeholder group in life cycle optimisation of buildings)
- Life cycle optimised buildings
- Branding

	From state of the art to short term	From short to medium term	From medium to long term
Drivers	Increase EE requirements	Enhanced regulations for EE of buildings Integration of renewable energy sources	EE driven business
Barriers	Lack of interoperability Unavailability of EE data about materials and products	Incompatibility of business incentives for design vs. whole life cycle performance Simulation tools are not fully interoperable with design tools	Prevailing business models focusing on delivery costs instead of value to client
Impacts	Compliance at lowest cost	EE services Life cycle optimised buildings	Branding EE design and production services

Table 2: Drivers, barriers and impacts of Tools for EE design and production management

4.1.4 Roadmap

A preliminary roadmap is depicted in the table that follows.

<table>
<tr><th>State of the art</th><th colspan="2">Short term</th><th>Medium term</th><th>Long term</th><th>Vision</th></tr>
<tr><td>Design: Discipline-oriented analysis and configuration management tools with discipline specific applications</td><td rowspan="2">Enhancement of existing design tools with EE features, EE aspects to catalogues of materials and products</td><td>Tools for EE conceptual design, model-based CAD tools, interoperable interfaces</td><td>Intelligent product catalogues, semantic search, libraries of best practices and reference design solutions, visualisations of EE design alternatives, long term archival and revival of BIM and other digital data, tools for validation of EE-compliance to building codes</td><td>Tools for configuration, management, self-optimising models, contractual and legal validity of BIM, and digital information</td><td rowspan="4">Integration of various functions, tools and communication between stakeholders

Contractual practices including valid verification of EE

Self-learning design system

Validation and certification of simulation software tools

Contracts based on models and life cycle EE performance.</td></tr>
<tr><td>Production management: Tools for scheduling, costing, procurement, logistics.</td><td>Material and product tracking systems, e.g. RFID, WSN etc.</td><td>Tools to optimise production EE as part of life cycle, collaboration platform for concurrent building engineering, model-based product design and production, agreeing and integrating information flows across the value network</td><td>Tools for rapid and flexible project team formation, contract configuration and management, model driven workflows, model-based as-built information available for operation and maintenance</td></tr>
<tr><td>Modelling: Document oriented tools.</td><td colspan="2">Enhancing current BIM models (IFC) with standardised EE attributes, model analysis and validation tools for EE, modelling of building energy profiles</td><td>Enhancement of data models (ontologies) to cover EE aspects Modelling of local energy generation related to buildings: PVs, wind power, RES, storage etc., modelling of user profiles</td><td>BIM servers for collaborative BIM based design
Integration of design models (BIM) with operational near-real-time information, integration of building and district level models</td></tr>
<tr><td>Performance estimation: Numerous distinct tools for cost estimation, life cycle assessment and energy simulation.</td><td colspan="2">Definition of EE performance indicators, easy input from tools for simulation, reduced time.</td><td>Standardise performance indicators at European level, performance estimation tools, comparison of performance information at the different stages of design-production-operation, development of test cases for simulation software tools.</td><td>Tools to estimate EE in a quantified and verifiable way - sufficient for performance based contracts, models, methods and tools to estimate EE performance of urban districts consisting of buildings, local generation and storage, interacting with energy grids, use of test cases to develop validation/ certification process.</td></tr>
</table>

Roadmap 1: Tools for EE design and production management

4.2 Intelligent control

4.2.1 Vision

Full energy-efficiency benefit is harvested through collaborating subsystems and optimal predictive control balancing the trade-off between comfort and energy consumption, local production and storage. Buildings are collaborating on district and city level and building controls are automatically interacting with the smart grid in able to exploit maximum amount of renewable energy sources on-site and level the use to avoid peaks. The systems have self-diagnostics and provide a high degree of monitoring while protecting privacy of individuals. Building controls are derived and tuned based on dynamic building models that through simulation show the nominal energy consumption.

4.2.2 Key research topics

To increase energy efficiency through intelligent control requires research in several areas. Following presents some of the identified research topics in four categories:

Automation and control

- Enhancement of energy prediction models and tools
- Development of energy optimal coordination algorithms between applications such as HVAC, lighting, security, etc.
- Development of application of predictive controls considering weather forecast, demand response events and peak power constraints
- Generating optimal building controls from a Building Information Model (BIM)
- Development of real-time algorithms for energy-efficiency diagnosis
- Developing building controls responsive to smart-grid interactivity
- Enhancing optimal controls on district and city level
- Enhancing equipment manufacturers to provide dynamic models of their products enabling simulation

Monitoring

- Decreasing production and deployment cost of basic communicating meters
- Increasing data collection while protecting the privacy of individuals
- Embedding more intelligence in sensors to perform local analysis
- Developing self-diagnosing equipment detecting suboptimal energy performance

Quality of service

- Development of better interoperability and reliability of the technologies and systems
- Enforcement of detection of problems
- Embedding self-diagnosis in sensors
- Using virtual reality for diagnosis and repair
- Including sensors and diagnostics in building materials

Wireless sensor networks

- Development of communication standards ensuring multi-vendor interoperability. In particular for wireless communication supporting battery-less low-power devices.
- Definition of standardised roles and services for sensors
- Development of automatically adapting network topology
- Establishment of cost-effective deployment procedures

4.2.3 Drivers, barriers and impacts

	From state of the art to short term	From short to medium term	From medium to long term
Drivers	Dynamic energy prices.	Local production and storage of energy.	Regulations and standards for energy efficiency.
Barriers	Focus is more on capital investment than operational cost and savings during the lifecycle. ROI must be proven before investment decisions, which hindrances the launch of new products. Lack of interoperability between actors.	Insufficient interoperability. Security and privacy concerns	End-user acceptance.
Impacts	Increased demand for a Building Management System (BMS).	Sustained energy efficiency.	Improved district energy management.

Table 3: Drivers, barriers and impacts of Intelligent control

4.2.4 Roadmap

A preliminary roadmap is depicted in the table that follows.

<table>
<tr><th>State of the art</th><th>Short term</th><th>Medium term</th><th colspan="2">Long term</th><th>Vision</th></tr>
<tr><td>Automation and Control: Standardised solutions for control.</td><td>Coordinating algorithms between applications.</td><td>Predictive control considering weather forecast, make building controls responsive to smart-grid interactivity.</td><td colspan="2">Generate optimal building controls from BIM, optimal controls on district and city level, equipment manufacturers provide dynamic models of their products enabling simulation.</td><td rowspan="4">Collaborating subsystems and optimal predictive control.
Collaborating buildings on district and city level and interaction with the smart grid.
Self-diagnostics systems with high degree of monitoring while protecting privacy of individuals.
Building controls are derived and tuned based on dynamic building models that through simulation show the nominal energy consumption.</td></tr>
<tr><td>Monitoring: Monitoring as a standard component in a modern BMS and measurements used for building control stored in trend logs.</td><td>Decrease production and deployment cost of basic communicating meters.</td><td>Increased data collection while protecting the privacy of individuals, embed more intelligence in sensors to perform local analysis.</td><td colspan="2">Sensors are built in the fabric of the building.</td></tr>
<tr><td>Quality of service: Basic self-diagnosis commonly available in automation control products. Large quantity of self-diagnosing functionality with associated alarms.</td><td>Enforce that detected problems get attended, develop real-time algorithms for energy-efficiency diagnosis.</td><td>Embed self-diagnosis in sensors, self-diagnosing equipment detecting suboptimal energy performance.</td><td>Use of virtual reality for diagnosis and repair.</td><td rowspan="2">Inclusion of sensors and diagnostics in building materials.</td></tr>
<tr><td>Wireless sensor networks: Wireless technologies for building automation available, but there’s a lack of interoperability between different vendors.</td><td>Develop communication standards ensuring multi-vendor interoperability and supporting battery-less low-power devices, establish cost-effective deployment procedures.</td><td>Define standardised roles and services for sensors, automatically adapting network topology.</td><td></td></tr>
</table>

Roadmap 2: Intelligent control

4.3 User awareness and decision support

4.3.1 Vision

ICT supports understanding, capturing and formalising customer/client needs into requirements, conveying them to all stakeholders and validating compliances. The impact of ICT on EE is well understood thanks to the diffusion of model-based evidence. Standardised methods and indicators are available for decision-support to assess and benchmark the energy performance of districts, buildings, systems and components. Performance audits, labelling and continuous commissioning are supported by recorded data of real time performance.

Main roles of ICT in awareness and decision support are to:

- Provide information to users of buildings, owners, facilities managers, local authorities and urban planners about energy consumption
- Enable occupants to control devices in buildings in order to decrease consumption
- Make occupants aware on how their activities will influence energy use from short and long term perspectives
- Motivate and support behaviour changes by highlighting other factors that affect energy usage (like demographics, family composition)

Information is the key issue in supporting decisions and creating awareness. It is easily available, comprehensible and useful for further operations through various interfaces and taking advantage of gaming and mixed reality. It is possible to gather information about many environmental factors (temperature, humidity, CO_2 concentration, solar radiations, etc.) and predict possible energy use.

4.3.2 Key research topics

Performance Management

- Implementation of performance analysis and optimisation by using the information collected during the monitoring, and take corrective/optimisation measures to improve the energy efficiency.
- Forecasting of energy demand by taking into account not only the current building operation conditions but also its expected evolution, which depends on the weather forecast and the scheduled building usage profile.
- Development of a multi-dimensional visualisation system of parameters of building operations and data sharing from technical systems;
- Definition of performance metrics and policy marker.
- Use of product Integrated Virtual Energy Laboratory (IVEL) as quantifying tool for measuring energy performance, consumption and costs throughout building's life cycle;
- Development of Decision Support System (DSS) that exploits comprehensive and transferable indicators easily understood by urban planners to find the best integrated building concept, and user to find the best way to control their buildings. With the momentum of green design, new technologies and applications are continuously being developed to assist in sustainable living. A large percentage of energy is consumed in buildings, majorly impacting our individual carbon footprint. By monitoring buildings' energy consumption in real time with a web or mobile application users can pinpoint vampire devices, times of high or low consumption, and wasteful patterns of energy use.

Visualisation of energy use

- Development of new human-machine interfaces (HMI) and smart energy meters incorporated into BMS is important to provide real-time information on energy consumption in building. Web accessible "energy account" could provide users a usable device to have real-time control on energy consumption and an intuitive way to understand how to modify their daily behaviour that affects energy consumption. Intuitive applications will help users to quickly understand their usage habits by clearly identifying total consumption as well as individual device consumption. This kind of applications and devices installed in buildings can help in obtaining valuable information. Users will be able to turn on electrical appliance in the most appropriate moment to reduce energy or when the net will be less charged using their smart phones being away from home or using television for example.
- Improvement of integrated energy visualisation tool in order to provide users a detailed vision of their individual carbon footprint considering the overall of daily activities they performed is needed. However, the development of common rules as a base for readable reports on energy consumption to end-users is needed.
- Development of user interface
- Dissemination of energy consumption information in an attractive way by using accessible interface
- Increasing of the knowledge of end-user needs (cultural context, comfort, user's behaviour, etc.), exploiting intelligent system for data management. This could be done with the help of new stakeholders such as sociologists.
- Identifying of 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, 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.

Behavioural change

Creation of paperless on-line solutions to easily display up-to-date drawings and other construction related materials on site:

- Showing evidence and demonstrate the comparison of investment and operational costs with the achieved energy savings and energy efficiency improvement.
- Development of intelligent and usable e-learning system that allows changing residents' behaviour as a result of ICT in order to increase its added value. These systems will help citizens to improve their behaviour by learning new ways of conducting daily activities. The user-friendly websites become the "gym" where users, easily from their house, could learn the merits and methods of energy conservation in order to reduce energy consumption and save money.
- Development of tools for comparison at neighbourhood level or with similar unities, e.g. family composition and user density within the building.
- Development of on-line tools to verify the adequacy and compliance with the Energy Performance of Buildings Directive (EPBD).

4.3.3 Drivers, barriers and impacts

The main drivers to increase users to get aware of energy consumption and efficiency from short and long term perspectives are represented by the:

- Identification of individual knowledge
- Improvement of energy information management
- Reduction of technological cost and energy consumption
- Identification of European standards and common metrics

In addition, it is important to train occupants to understand that they are a key component in the building and of any EE strategy.

Any technology that hopes to affect energy use, especially by individuals, must take into account the "**motivation of the users**", i.e.

- What does each individual really care about?
- What motivates him or her?
- What lifestyle do they have / would they like to have?
- What are the person's desires?
- Is it to have fun?
- To be comfortable?
- To make a difference?
- To become more integrated into the community?

Therefore, the best technology would tap into a person's motivations, lifestyle and habits would enable him/her to better understand and be able to make aspiration, fun, 'desirable' lifestyle choices that would have the effect of reducing energy. Technologies are progressing with increasing velocity and the knowledge of people, who must make decisions and act upon to meet energy reduction targets, is easily lagging behind.

Furthermore "**social pressure**" is one of the best means of getting people involved in changing behaviour, and that technology that enables EE in the next 10 years or sooner would need to enable social sharing.

As a key barrier people are usually not willing to adopt new things especially if it requires a change in their behaviour. They have had gained habits through the years and it is not easy to convince them to change. Otherwise, people are reacting when they are dissatisfied with a situation. So it is not about a lack of willingness, but about a lack of triggers: this clearly indicates that one of the needs for large spreading of ICT for energy efficiency is thus identify the right direction to make people reacting. Therefore presented solutions have to be user friendly as much as possible as well as relevant and effective.

Designers, architects and civil engineers can use different software tools supporting their decisions, however mostly they are not operating with the same format standard. The **identification of European standards and common metrics is** fundamental to have regulation that allow to obtain a reference metric that can be used across different European Countries. There is a general trend to make uniform data standards, but also special engine software tools available (like FME - Feature Manipulation Engine) that are able to transform a format into another. Moreover, from the standardisation point of view it would be useful to have a complete list with energy features for each material product for instance in the field of construction.

From the impact point of view the users and owners of buildings will be the main beneficiaries as they will be empowered to make informed decisions about the building and its use. Although technology is only one of the available tools that could be used to achieve energy saving and that in order to achieve maximum impact, ICTs would need to be combined with non-ICT tools in a suite of energy efficiency measures available to users.

	From state of the art to short term	From short to medium term	From medium to long term
Drivers	Cost reductions	Motivation of the users	Social Pressure
Barriers	Lack of data related to energy use profiles Concerns over privacy and security	Lack of European standards and common metrics Lack of multi-disciplinary approaches/solutions to EE	Peoples habits
Impacts	ICT is be combined with non-ICT tools in line with energy efficiency measures available to users	Users and owners make informed decisions about the building and its use.	Life cycle optimised buildings. Users as active players in energy market.

Table 4: Drivers, barriers and impacts of User awareness and decision support

4.3.4 Roadmap

The following figure illustrates the roadmap for intelligent and integrated control. It covers the current state-of-the-art and research priorities in the short, medium, and long term.

<table>
<tr><th>State of the art</th><th>Short term</th><th>Medium term</th><th>Long term</th><th>Vision</th></tr>
<tr><td>Performance Management: Standardised indicators available for assessing energy performance of buildings, systems and components.
Performance audits, labelling and continuous commissioning are supported by recorded data of real time performance.</td><td>Technologies those are capable of balancing the levels of automation and individual choice, performance database.</td><td>Integrating personal energy use between different building contexts, privacy and security, automatic tuning of the intelligent BMS (parameterisation), energy parameters database, and interoperability with real-time diagnostics, where estimated (designed) and observed (actual) performance can be compared.</td><td>Combination of ICT tools with non-ICT tools for obtaining an effective impact, heterogeneity of the system, definition of common standards and metrics at Euro.</td><td rowspan="3">There are smart, fun and easy to use tools, which exploits real time energy consumption information and help the different stakeholder to define the level of efficiency of the building.

Visualisation of energy use will be ensured by using internet accessible, smart, and usable interface, which provides useful suggestions to change habits to decrease energy consumption and costs.</td></tr>
<tr><td>Visualisation of energy use</td><td>Attractive Interfaces for energy visualisation, increase the knowledge of end-user needs, identification of the level of individual knowledge that each user must have about the buildings in which he lives or works in.</td><td>Exploit social pressure as a driver for motivating users on energy efficiency themes</td><td>Organise training sessions and e-learning websites for final users involvement</td></tr>
<tr><td>Behavioural change: Technologies are available to be used improving the level of user awareness.</td><td>Real-time internet accessibility to control your building consumption, development of energy bank database.</td><td>Increasing involvement of building users and owner on the use of BMS.

Reduce technological costs for end users.

Definition of attractive energy contracts for end users.</td><td>Daily energy consumption plan act to follow the scheduled activities planned by users.</td></tr>
</table>

Roadmap 3: User awareness and decision support

4.4 Energy management and trading

4.4.1 Vision

Energy Management and Trading are seen as key issues in the emerging future energy infrastructure. Buildings are no longer seen as standalone entities but as an integral part of a larger ecosystem both internally (within the subsystems of the building) and externally (with other smart city entities e.g. buildings, transportation system, public lighting, etc.). Within the buildings themselves, intelligent devices are monitoring and actuating autonomously its behaviour in order to achieve the desired functionality. Users are now able to interact with the building and configure it to fulfil their needs, event temporarily; this is possible only because a new generation of energy services enable this kind of interaction. Several optimisations take place at local and building wide level considering the internal as well as external conditions.

Buildings are no longer striving towards energy optimisation only at building-wide level but also consider district or even smart citywide constraints. As such they may collaborate with nearby buildings in order to achieve energy efficiency. Additionally they collaborate within a smart city infrastructure e.g. the transportation system and use their resources (internal operations, electric vehicles on their parking place, etc.) to assist the optimal electricity network operation e.g. acting as an energy-balancing partner. With the emerging opportunities that the smart grid offers, buildings can now buy and/or sell electricity on available marketplaces, intelligently plan their energy behaviour and even provide new revenue sources to their owners by adjusting flexibly their behaviour to demand-response conditions from the electricity grid.

The buildings of the future will be part of a live ecosystem that will heavily interact and collaborate with users and external entities to optimally manage their energy footprint locally and as part of the ecosystem.

4.4.2 Key research topics

From the research perspective there are several issues that need to be investigated. Some of these include:

- Migration towards open and fully service-based infrastructures
- Adoption of collaboration tools for open cross-industry information exchange
- Enhancement of energy prediction models and tools
- Development of energy optimisation and control models and tools
- Development of real-time consolidated reporting and integration with business processes
- Development of models and methods for assessment and comparison of energy footprint during the whole lifecycle
- Development of tools for security, privacy and trust assessment
- Scalable integration of buildings with Smart Grids and Smart Cities
- Development of internet based energy services for smart buildings
- Easy integration with online energy marketplaces
- Easy integration of alternative energy resources and demand-response management

- Development of tools for the assessment of approaches during their whole lifecycle including cost, environment impact, maintenance etc.

4.4.3 Drivers, barriers and impacts

There are several stakeholders that will directly or indirectly impose drivers. The key drivers may come from the quest towards energy management and efficiency and be driven by key stakeholders such as DSO, facility management, etc. The enabling ICT technologies may be provided by the market players who will drive them. Economic and Policy/Regulation reasons imposed at European wide level may also push towards this direction.

Potential barriers include:

- Lack of awareness on innovation for energy management as part of an ecosystem
- Lack of demonstrating clearly the benefits in real-world lighthouse projects
- Lack of market availability and openness
- Lack of policies and incentives at national and European wide level
- Difficulty overcoming established energy systems and providing migration solutions to next generation open collaborative energy management
- Inadequate workforce skills and training
- Lack of ICT tools for enabling interaction of all stakeholders
- Lack of business adaption and availability of value added services
- Security concerns
- Privacy concerns
- Non-interoperable data exchange formats
- Failure to anticipate the lifecycle management i.e. from cradle to grave for the maintenance of large scale systems
- Focus on standalone solutions and goals and failure to consider collaboration at all layers.

Significant economic, social and innovation impact may be achieved. We see three distinct directions relevant to Energy management and trading:

- Building Energy Management: Here significant impact could be achieved, tackling energy efficiency and with the first results already available in the short-term.
- District Energy Management: Significant impact could be achieved in the mid and long term that could lead to optimal energy management at district and smart city level.
- Smart Grid and the Building Environment: Integration with the Smart Grid and optimal consideration of the Building environment and advances in other sectors e.g. construction could both lead to high impact and act as an enabler for energy efficiency.

	From state of the art to short term	From short to medium term	From medium to long term
Drivers	Stakeholder driven	Economic reasons e.g. increased energy prices	Policy/Regulation at EU level and EE driven business in view of an open and free energy market
Barriers	Technology, market, social barriers may appear	ICT tools for enabling stakeholder interaction	Business adaption and availability of value added services
Impacts	Significant impact in BEMS	Significant impact in District Energy Management	Integration with Smart Grid and the Building Environment

Table 5: Drivers, barriers and impacts of Energy management and trading

4.4.4 Roadmap

A preliminary roadmap is depicted in the table that follows.

State of the art	Short term	Medium term	Long term	Vision
Building Energy Management: Several (also commercial) isolated solutions available dealing with energy management in buildings (not interoperable). Limited number of smart appliances available.	Adoption of open and interoperable solutions, service wrapping of existing functionalities, information exchange between building's subsystems, enhancing and extending existing energy management.	Deployment of intelligent devices, provision of (mobile) internet based user services, adjustment of the building behaviour to users' plans.	Provision of complex user services, real-time fully automated energy management and adjustment to dynamic conditions, collaboration with other buildings and systems.	Flexible building energy management adjustable to user's as well as external needs. Integration of intelligent devices and accurate forecasting by context information integration. Interoperable energy management solutions beyond standalone systems/buildings. Real-time energy management depending on Key Performance Indicators. Real-time Demand-Response depending on local resource availability. Buildings should collaborate with the local district for energy efficiency. Collaboration of buildings with each-other Collaboration with the smart grid markets
District Energy Management: Energy Monitoring solutions available (not real-time), energy info is available in silos of solutions for the different district systems, hardly any energy services for the citizens	Energy monitoring at district level, opening of functionalities and provision of services.	District Energy services for end-users, deployment of district-wide energy management, citizen energy services and best practices, privacy and security assessment tools.	Real-time adjustment and optimisation of district's energy management to conform to KPIs, full integration with all parts of the smart city (including public infrastructure, transportation etc.), energy Simulation and model availability for districts.	
Smart Grid and the Building Environment: Smart metering is an issue under development, energy monitoring services for citizens.	Smart metering, energy awareness via monitoring services.	User participation on district energy marketplaces, value energy added business services	Real-time demand-response solutions, participation of prosumers to groups and free energy trade, automated Intelligent Energy management for virtual groups of buildings/users, market-driven energy services	

Roadmap 4: Energy management and trading

4.5 Integration technologies

4.5.1 Vision

The dynamic nature of design projects requires parallel processes, smooth workflow and tight control. There are applications to give support to all these needs and allowing different profiles of experts work together in a project with no difficulty related to coordination of processes and the shared control of the entire project. These kinds of applications offer smart workflows that are synchronised automatically depending on the status of the project without any help.

Embedded diagnostics methods, which are capable of running on local controller devices, allow early detection of anomalous energy consumption and/or malfunction of individual components (dampers, valves, coils, etc.) in sub-systems such as air handling, heating, cooling, or lighting. Load management algorithms consider future energy consumption and based on that adjust the consumption curve by shifting or curtailing some of the loads. In case of system optimisation, the control strategy uses the information about the operation states, loads, weather conditions, tariffs, and equipment characteristics.

Data models and real-time communication protocols are 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. Devices from different producers are in use at the moment when plugging them, because all the devices inside and outside the buildings share the same protocols. Other domains protocols and standards are integrated as needs and applications of buildings will increase.

The information from different stakeholders is shared between them using inter-organisational knowledge platforms, where the information is organised by term and which offers an easy way to be consulted.

4.5.2 Key research topics

Nowadays, in the design and construction process of a building, very different approaches are needed, which leads to engage in the process different kind of professionals within their respective role in the project. Taking it into account and also the increasing complexity of the buildings in order to improve their efficiency, leads to a very high demand of ICT tools to achieve the objectives:

- A collaboration tool between all the stakeholders involved in the project in order to interact between them in the building life cycle.
- Better implementation of building lifecycle by changing the point of view regarding the importance of its energy costs.
- New embedded devices for monitoring and control the energy consumption in the buildings and in a lower level, taking into account each flat/office that compounds the building.
- Better tools to share and generate the knowledge between all the stakeholders involved (e.g. cloud technology).

The technological development that is requested to satisfy these demands has been structured in the following RTD topics:

- Process integration: focused in the development of reliable and useful tools in relation with collaboration and business work flows. In fact, it is one of the most interesting and key areas of research in order to end up with a tool capable of make efficient the interaction between all the roles involved in the projects.

- System integration: related with integration platforms and services supported, SOA, Middleware, Development methods and tools as Integrated design environments (IDE), embedded devices for control and monitoring of consumption, data modelling methods, Plug&Play. Identifying and understanding the borders of systems or between stakeholders is essential.
- Interoperability and standards: related with research areas involving data models and real time (in-side and out-side building) communication protocols. Rapid development of coherent standards for interoperability is needed. These standards should contemplate future systems and the broader range of applications that are being envisaged now. Moreover, improved interoperability must therefore be a core element of all future initiatives.
- Knowledge sharing: management of the access to knowledge using a platform with repositories, forums etc. with a user profile to split the users depending on their role and area of expertise. Also including data mining and semantic search.

4.5.3 Drivers, barriers and impacts

One driver to be taken into account that enhance the technological changes in relation with ICT for energy efficiency buildings is the social awareness about the problem of the Climatic Change and its relation with the building's energy consumption. On the other site, it's necessary to consider the presence of internet in most of homes and offices that gives more technological options to develop embedded software and devices to balance the consumption and the generation of energy in buildings as well as the real-time monitoring and control. New protocols like IPv6 will ease the communication and integration between different devices inside and outside the buildings as well as the implementation of the Smart Grid concept.

The main barrier at this point is the lack of knowledge about the importance of the adoption of a building life cycle in relation with energy cost. As we know, a lot of stakeholders take part in the building life cycle and usually most of them are not big companies. Therefore most of them are focused in their role on it and it's difficult to find any stakeholder that can lead the adoption of it overall the whole process.

The difficulty that represents to adapt the existing building to the new approaches of energy efficiency in buildings is another barrier at this point. It's clear that the installation needs to be automated and more complex and no always it is possible without a big investment.

Expected benefits and business opportunities to key can be summarised in the following ones:

- Better knowledge about building life cycle energy performance and the importance of its adoption regarding reduction in building project execution times and costs and higher quality of the buildings
- Implementation of the smart-grid concept. Higher integration of buildings in the energy networks will allows exploiting the building's energy generation and storage capabilities and their associated equipment, as future electric cars.
- New business opportunities for ICT, energy and building sectors.
- Higher sustainability with lower resource's consumption (i.e. travel, energy, etc.) via changes to the way we work.
- Achieve a standardisation regarding communications and protocols to ease the interoperability and the communication among different devices.

- Share of knowledge among all the stakeholders involved in energy efficiency.

	From state of the art to short term	From short to medium term	From medium to long term
Drivers	Citizen awareness regarding the importance of energy efficiency Development of common protocol for communication	Embedded software and devices to balance the consumption and the generation of energy in buildings Importance of energy auto generation in buildings	Load management algorithms to consider future energy consumption
Barriers	Difficulty that represent to adapt the existing building to the new approaches of energy efficiency in buildings Lack of knowledge about building life cycle energy costs	Different protocols and communications coexisting in the market Difficulty to agree in a common protocol for communication inside and outside the buildings.	Access to the knowledge generated in all the fields related to energy efficiency in buildings
Impacts	New business opportunities for ICT, energy and building sectors Change of mentality regarding the importance of energy efficient in buildings Better implementation of building lifecycle by changing the point of view regarding the importance of its energy costs.	Achieve a standardisation regarding communications and protocols to ease the interoperability and the communication among different devices Implementation of smart grids	Share of knowledge among all the stakeholders involved in energy efficiency New algorithms to plan and forecast the consumption in buildings.

Table 6: Drivers, barriers and impacts of Integration technologies

4.5.4 Roadmap

The following figure depicts the Roadmap:

State of the art	Short term	Medium term	Long term	Vision
Process integration: Rude applications to integrate different roles in a project.	Improvement of the rude applications existing in the market.	Applications that will allow the control of parallel processes done by different kinds of experts involved in a project.	Development of smart workflows in this kind of applications due to the dynamic behaviour of these projects.	Parallel processes, smooth and smart workflow and tight control. New applications to support all these needs allowing different experts work together in a project
System integration: Coexistence of various communication protocols and devices	Systems integration from building level to neighbourhood level.	Networked 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.	Early detection of anomalous energy consumption and/or malfunction of individual components by using embedded diagnostics methods, which are capable of running on local controller devices
Interoperability and standards: Non interoperability among devices and non-complete standards	Agreement on the protocols and communications that fit better with the needs of the vendors and the existing devices.	Advancement of technology standards development and general adoption by most of the vendors.	All the devices inside and outside the buildings will share the same protocols.	Standardised data models and real-time communication protocols are allowing all the stakeholders to develop their devices without problems of interoperability
Knowledge sharing: Different allocations for knowledge share and difficulty to find it.	Use of common forums and collaboration spaces to share the knowledge.	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	Improvement of seek methods in the common platform to allow a good access to huge amount of information related to all kind of fields.	Knowledge of all stakeholders involved in construction and energy efficient buildings issues will be shared between them using inter-organisational knowledge platforms that contain all the information organised by term and will offer an easy way to be consulted.

Roadmap 5: Integration technologies

5 Updated Implementation action plan

Final updated recommendations will be developed in the ICT4E2B forum on the forthcoming project deliverable D2.4, after stakeholder's feedback on the draft roadmap presented in this document.

In the REEB project [1], using the roadmap as a foundation, a call for research topics/ideas was launched to different stakeholders to solicit RTD topics supporting realisation of the roadmap. The survey was done using the questionnaire on the next page. Altogether 63 topics/ideas were received covering all of the 5 main categories. The received implementation action proposals were analysed and consolidated into recommendations regarding different innovation stages, covering:

- Policies: regulation, taxation, setting up large-scale actions / programmes etc.
- Coordination: roadmaps, think-tanks, working groups, studies, supporting innovation and research programs, facilitation of communication between different initiatives and communities etc.
- RTD: tolls for energy efficient design and production management, intelligent and integrated control, user awareness and decision support, energy management and trading, and, integration technologies.
- Take-up: dissemination, promotion, awareness creation, demonstrations / pilots.
- Standardisation: interfaces, models, protocols, reference architectures etc. concerning convergence of ICT standards across sectors
- Education and training

Implementation of these recommended actions is envisaged to lead to key industrial transformations within the construction sector though the role of ICT for energy efficiency in buildings as follows:

- Life cycle approach: Integrated design teams, using interoperable model-based tools and communication/collaboration platforms optimise the whole life performance of buildings.
- Smart buildings: Most buildings will be "smart" and control themselves maintaining the required and optimal performance and responding proactively to external conditions and user behaviour anticipating them, rather than reactively. Holistic operation of subsystems is supported by integrated system architectures, communication platforms, standard protocols for interoperability, sensors, and wireless control technologies.
- Construction as a knowledge based industry: Industrialised solutions are available for configuring flexible new buildings as well as retrofitting existing buildings. Customised solutions are developed by configuring re-usable knowledge from catalogues within organisations and industry-wide.
- Business models and regulations are driven by user perceived value. Financing models provide incentives to stakeholder towards whole life performance of buildings. ICT tools support performance measurement, validation and holistic decision making.

6 Conclusions

6.1 Comparison against the Description of work (DoW)

The REEB roadmap was used as baseline and complemented with EeB PPP Multi-annual Roadmap to derive the updated roadmap consisting of vision and SRA presented in D2.3. The implementation activity plan will be developed based on the feedback and presented in D2.4. Following figure represents the process:

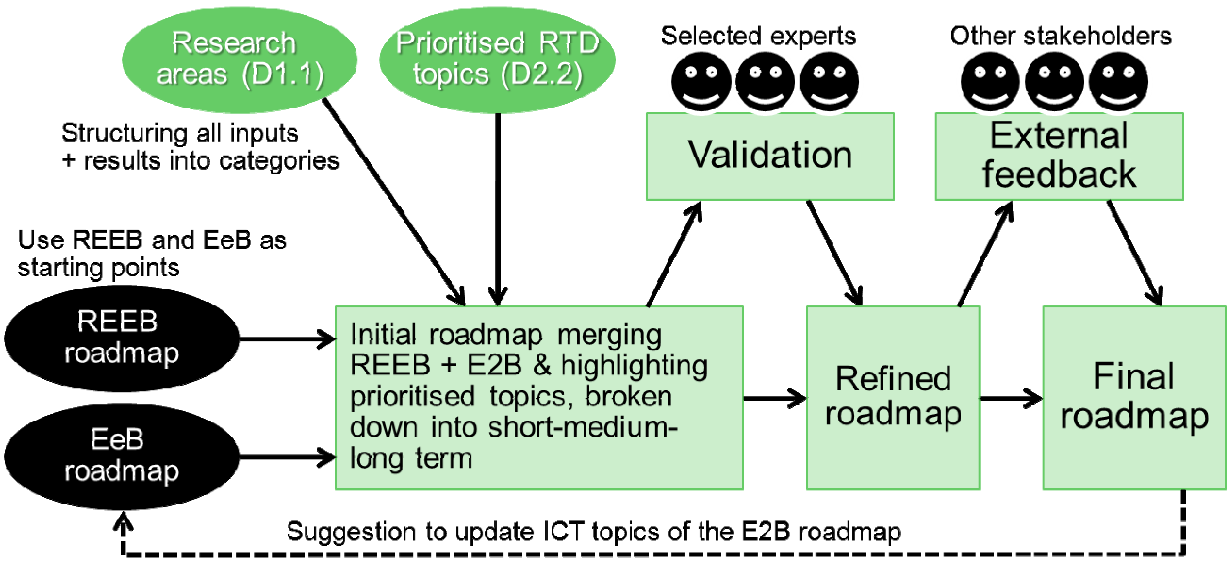

Figure 5: Methodology based on the DoW

Following tasks will be executed during the year 2012 and reported in D2.4 including the revising of the roadmap based on the feedback from stakeholders:

- Selected experts will be involved to elaborate synergies and multidisciplinary areas of research within the EeB PPP Multi-annual Roadmap and its Implementation Plan.
- The initial version of the roadmap will be presented at the validation Workshop (organised by WP4) with the experts group for feedback on contents and priorities.
- The refined Research Roadmap will define objectives and timeframe for future research topics and activities: multi-disciplinary research, demonstrations, dissemination, best practice promotion, education and training, innovation policies, standardisation etc.

6.2 Main findings

Previous work conducted in REEB and EeB provided a solid ground for the research roadmap presented in this document. New technologies were not identified; however the developments in interoperability and standardisation might lead to the consolidation of existing technologies. An increasing focuses and overall change to user-centric and district level solutions can be seen.

7 Acronyms and terms

3D	Three Dimensions
AIAG	Ad-hoc industrial Advisory Group
BEMS	Building Energy Management Systems
BIM	Building Information Modelling
BMS	Building Management Systems
CAD	Computer Aided Design
Cloud technology	Computing as a services, which includes different compilation of hardware, networks, storage, services, and interfaces
CO_2	Carbon di Oxide
DoW	Description of Work
DSO	Distribution System Operator
DSS	Decision Support System
E2BA	Energy Efficient Buildings Association
EE	Energy Efficiency
EeB	Energy- Efficient Buildings
EPBD	Energy Performance of Buildings Directive
ESCO	Energy Services Company
ETPs	European Technology Platform
EU	European Union
FME	Feature Manipulation Engine
FP	Framework Programme
HMI	Human-machine interfaces
HVAC	Heating Ventilation and Air-conditioning
ICT	Information and Communication Technologies
ICT4E2B	ICT for Energy Efficient Buildings
IFC	Industry Foundation Classes
IPD	Integrated Project Delivery
IPR	Intellectual Property Rights
IPv6	Internet Protocol version 6
IVEL	Integrated Virtual Energy Laboratory
JTIs	Joint Technology Platforms
KPI’s	Key Performance Indicators
PPP	Public-Private Partnerships
PV	Photo Voltaic
R&D	Research and Development
RFID	Radio Frequency Identification

RTD	Research and Technology Development
ROI	Return on Investment
SRA	Strategic Research Agenda
SOA	System Oriented Architecture
WSN	Wireless Sensor Networks

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