ICT FOR ENERGY EFFICIENCT BUILDINGS: PROPOSED APPROACH FOR A STAKEHOLDERS-BASED STRATEGIC ROADMAP

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ABSTRACT

ICT4E2B Forum project aims to bring together all relevant stakeholders involved in ICT systems and solutions for Energy Efficiency in Buildings. Moreover the project has the objective of identifying and reviewing the needs in terms of research and systems integration as well as at accelerating implementation and take-up. ICT4E2B Forum bases its roadmapping activities on the outputs of REEB project that has already developed a high-level roadmap on ICT for Energy Efficient Buildings. Starting from this expert-based work, ICT4E2B Forum 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. The exploitation of ICT is consider the adding value in order to support informed decision-making (both human and automated) in the current delivery and in the use of sustainable and energy-efficient buildings and districts. By accomplishing these objectives, ICT4E2B Forum is mapping the sector-specific priorities into a common view and vocabulary, thereby enabling communication and understanding between experts in different sectors that need to join forces in order that fundamental improvements in energy efficient buildings can be achieved. All this coordination work will support in defining future research directions as well as in channelling efforts, while favouring consensus buildings on the roadmap itself.

Keywords: Energy-efficient buildings, ICT4E2B Forum project, REEB project, Strategic Roadmap, Stakeholder-based.

1. INTRODUCTION

Nowadays it is widely recognized that the great energy savings potential of the introduction of ICT technologies should be considered along the whole life-cycle of the built environment. On the other hand the large set of potentially exploitable ICT technologies and the wide possible use-cases that can be considered in the whole building life-cycle, make necessary a prioritization of the efforts, identifying the most promising technologies and the most effective use-cases in order to efficiently direct the R&D efforts on the upcoming years.

There are several examples of such technology roadmaps developed or under development by field experts, but in most of the cases the presented visions lack, even if they are very relevant from a technical/scientific point of view, a consistent contribution from the stakeholders involved in the whole value-chain. There is a need to provide a wider vision not only from the technical point of view, but also from societal, economic, market, end-user and several other perspectives.

Within this framework ICT4E2B Forum project aims to fill the above mentioned gaps by bringing together all relevant stakeholders involved in ICT systems and solutions for Energy Efficiency in Buildings, and the project aims at identifying and reviewing the needs in terms of research and systems integration as well as accelerating implementation and take-up.

It is important to underline that ICT4E2B Forum bases its roadmapping activities on the outputs of REEB project. This project has already developed an high-level roadmap on research and technology development in the area of ICT for Energy Efficient Buildings, therefore ICT4E2B Forum starting from this expert-based work, intends to promote, through community building activities, a better understanding, a closer dialogue and a more active cooperation between all the players of the building sector.

With reference to the above objectives, ICT4E2B Forum is identifying the building sector-specific priorities, organizing these into a structured classification, thereby enabling communication and competences/knowledge sharing between experts in different sectors that are joining their forces in order that fundamental improvements in energy efficient buildings can be achieved.
All this coordination work will support in defining future research directions as well as in channelling efforts, while favouring consensus buildings on the roadmap itself.

The aim of this paper is to present the approach proposed within the project. In Section 2 there are details on the main results of REEB project that will constitute a baseline for following activities. Section 3 represents an updated overview of the Industrial State-of-the-Art that will act as reference term for the proposed roadmapping. Finally in Section 4 there the proposed approach for the ICT4E2B roadmap preparation is outlined.

2. RESULTS FROM REEB AS A BASELINE FOR ICT4E2B FORUM

This section is based on the REEB project. The REEB coordination action (European strategic research roadmap to ICT enabled Energy - Efficiency (EE) in Building and Construction) was an initiative to identify the current state-of-the- research and best practices. The objective was to provide a vision in form of a strategic research agenda (roadmap) with supporting implementation recommendations for ICT supported energy efficiency in construction. During the REEB project, following items were covered:

- State-of-the-art and best practices related to the subject
- Gap analysis of research and technology development initiatives
- Structured roadmaps based on industrial priorities
- Recommendations for different innovation stages: policy, coordination, research and development, take-up, standardization, and education and training

In order to understand the transformation of focus from the initial construction cost to whole life performance, 12 key best practices, as described in **Table 1**, were developed based on lessons from more than 80 case studies.

✓ Simulation based energy design	✓ Early energy design	✓ Smart grids
✓ Smart metering for energy consumption awareness	✓ Building Management Systems	✓ Wireless Sensor Networks for energy performance monitoring
✓ Standards based energy performance assessment software	✓ Energy performance audit solutions	✓ Integrated Modeling solutions based on Building Information Modeling
✓ Websites for collecting and disseminating energy-efficiency	✓ Standards-based solutions for building life-cycle management	✓ Standards-based energy data exchange solutions

Table 1: Key Best Practices described as a result of REEB

During gap analysis of research and development initiatives, five main categories of research were identified based on ICT trends and a review of more than 270 relevant projects of which 52 were more intensively analyzed. The identified research areas are as presented in the following **Figure 1**.

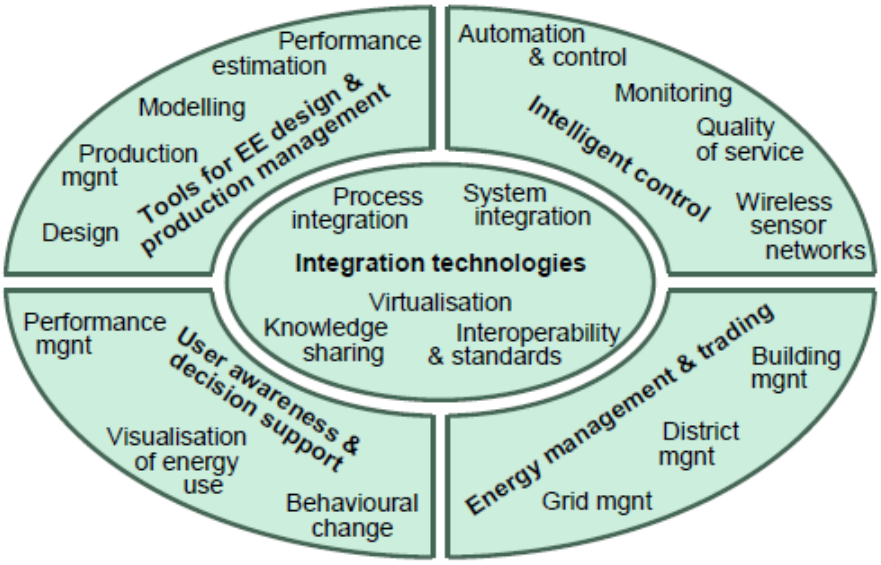

Figure 1: Key RTD areas for ICT enabled Energy Efficiency in Buildings

For each of the five areas, detailed roadmaps were developed as illustrated in **Figure 2**. The roadmaps covered a vision illustrated by exemplary business scenarios, drivers, barriers, impacts and short, medium, and long term research priorities.

Drivers	Increasing EE requirements.	Life cycle optimised buildings.	EE driven business.
Barriers	Lack of interoperability. Need of many special tools and extra efforts for EE considerations.	Lack of client awareness, incentives and financial instruments. National / regional regulations.	Prevailing business models focusing on delivery costs instead of value to client.
Impacts	Compliance at lowest cost.	EE services.	Branding.

State of the Art	Short term		Medium term	Long term	Vision
Design: Discipline-oriented analysis & dimensioning tools. General purpose CAD with discipline oriented add-ons.	Enhance-ment of existing design tools with EE features.	Tools for early stage design. Interoperable interfaces.	GUIs for data filtering, navigation and visualisation. Catalogues with EE aspects. Advanced analysis tools.	Specialised tools for "creative design" and "configuration mgnt". Template solutions for customised configuration.	Integrated model-based tools with embedded consideration of EE aspects in a transparent way. Catalogues of all re-usable knowledge. Standardised data model covering all EE aspects. Interoperability between all SW tools for design, production mgnt and operation. Contracts based on models and life cycle EE performance.
Production mgnt: Tools for contract & supply chain mgnt, procurement, logistics, on/off site production mgnt.		Material and product tracking systems.	Adding EE aspects to catalo-gues of materials and products. Tools to optimise production EE as part of life cycle.	Tools for rapid and flexible project team formation and mgnt.	
Integrated engineering: Web-based document mgnt systems.	Guidelines for integrated design.		Collaboration platform for concurrent building engineering.	Integrated design environment. Model driven workflows.	
Modelling: Mostly document oriented tools. Model based tools are emerging (e.g. BIM-CAD).	Take up of available model based tools.		Enhancement of data models (ontologies) to cover EE aspects.	Model servers. Integration of design models (BIM) with operational near-realtime information.	
Performance estimation: Numerous distinct tools for cost estimation, life cycle assessment and simulation.	Validation / certification of SW tools. Definition of performance metrics.		Integration of EE assessment with design tools. Interoperability with real time diagnostics.	Tools to estimate EE in a quantified and verifiable way – sufficient for performance based contracts.	

Figure 2: Key RTD areas for ICT enabled Energy Efficient Buildings

To guide towards realization of the required actions identified in the roadmaps, several implementation actions were recommended covering policies, coordination of activities, research and technology development, dissemination and awareness creation, standardization, education and training. Implementation of these recommended actions are envisaged to lead to key industrial transformations within the construction sector through the role of ICT for energy efficiency in buildings.

The results obtained by REEB have been validated by key stakeholders from ICT, energy and construction sector. However, there is a need to extend this to a much larger stakeholder forum for refinement, endorsement and implementation. This initiative has now been launched through the ICT4E2B 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).

3. OVERVIEW OF THE INDUSTRIAL STATE-OF-THE-ART

The focus of this section is on the review of Industrial State-of-the-Art, taking as reference the results of REEB project and in particular the Best Practices identified. With respect to those results, this work does not represents only an update, but it is a further step beyond since our review is based on real interesting cases available in the industrial context, providing therefore the actual technology baseline for the roadmap to be developed in the following of the project.

3.1 Industrial State-of-the-Art on Energy Efficiency design and Production Management

In the scenario of Energy Efficiency in building many stakeholders participate to building design, execution and operation of a building, but everyone has a specific role that defines what he is allowed to see and edit. Model management tools need to make possible the interaction among this large and dynamic group of stakeholders during the building life cycle and support multimedia contents. Design model tool as CAD (Computer Aided Drafting) tool, performance estimation tool useful for targeting cost estimation, life cycle assessment, simulation of energy usage and indoor conditions, and visualization of these analyses for decision support, and model management tools need to be based on common open standards that guarantee their interoperability with other ICT.

The definition of a common Building Information Modeling (BIM) for energy efficiency in buildings, bridging the gap between the building design and the building operation tools is actually missing. Poor integration of BIM-CAD tools, insufficient interoperability between all tools forming the chain of performance estimation, and the lack of appropriate data flows transporting the required semantic information, lead to a situation where the likely future performance of the building under design is hard to evaluate, especially in the early planning and design phases.

3.2 Industrial State-of-the-Art on Intelligent Control

It is not easy to understand the level of acceptance of Intelligent Control in the existing European building stock, in particular considering the fact that installed systems may not be activated.
In fact, existing automation and control algorithms are most often restricted to sub-systems, independent from each other, and hard-coded in the devices with little possibility to update or modify them by a centralized control instance. Despite that smart meters enable real-time electricity consumption reporting and visualization as well as bidirectional communication with smart grids it is necessary to analyze current sensors' drawbacks. In fact, all the needed sensors, with the required sensitivity and accuracy and with own communication protocols, currently are not available at reasonable cost for a large scale deployment and might include error detection with imply a wrong communication.

Nowadays, taking into consideration the need of cost reduction, the payback period for advanced control in small buildings is too high. A way of lowering the cost could be to have the functionality as

cloud-based services, where more users could share sub-systems of intelligent control architecture, and therefore lowering the need for local capital investment.

3.3 Industrial State-of-the-Art on User Awareness and Decision Support

ICT supports understanding, capturing and formalizing customer/client needs into requirements, conveying them to all stakeholders and validating compliances. The impact of ICT on Energy Efficiency is well understood thanks to the diffusion of model-based evidence. Standardized methods and indicators are available for assessing and benchmarking the energy performance of buildings, systems and components. Performance audits, labeling 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 about energy consumption
- enable occupants to control devices in their home 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. Information should be easily available, comprehensible and useful for further operations. It is possible to gather information about many environmental factors (temperature, humidity, CO_2 concentration, solar radiations, etc.) and predict possible energy use.

3.4 Industrial State-of-the-Art on Energy Management and Trading

Energy management and energy trading are two terms widely used throughout the industry in various matters. As such a general definition can be given, whereas the specific needs of energy management from a stakeholder individual perspective need to be taken into account.

Energy can be regarded as an asset that is needed by various stakeholders for their individual applications and in various forms. Overall energy management can be defined as to assure that all stakeholders across an organization obtain the energy they require when and where it is needed. Looking at energy as asset, energy needs to be procured in an economic, secure and sustainable manner.
The energy market is changing rapidly worldwide. Many markets have just recently been deregulated. It is necessary to form new types of players. These can be network operators, energy suppliers and power plant operators (producers) to name a few; all of these will be focused on how to procure, apply and potentially reuse energy in an economic, secure and sustainable manner.

In addition the complexity and volatility of a wholesale market can be better tackled by an entity which can reduce transaction costs with economies of scale, further applying a procurement strategy to deal with the risks that exist in wholesale markets.

3.5 Industrial State-of-the-Art on Integration Technologies

A full exploitation of the opportunities offered by ICT for energy efficiency requires changes of the processes and contractual practices of the construction sector. The importance of collaboration between different design disciplines has been widely recognized by the building industry. Traditionally this is achieved through physical meetings between the representatives of different design groups.

However, there are more challenges when dealing with large and complex design problems. Various approaches based on integration technologies have been introduced to face this problem, such as Multi-Agent Systems (MAS) and the Multi-disciplinary Design Optimization (MDO) approaches. The former represents an advanced, ICT-based framework which facilitates collaborative design through communication, data and knowledge sharing and negotiation while the latter represents a theoretical modeling approach which facilitates collaborative design through a thorough analysis of the technical problems.

The modern vision consider Building Automation (BA) domain and Building Management Systems (BMS) as "*Open Systems*" (an End-to-End solution that is **open**, **interoperable** and **multi-vendor)** for a full comprehensive building control network, designed on several types of bus systems, that:

- encompasses every building system,
- enable competitive bidding and allow best-in-breed product selection,
- have a dynamic application, being able to utilize enterprise technologies and present new opportunities and added value for manufacturers, system integrators and owners alike.

Selecting an appropriate Open System as BMS solution, it will be capable of delivering an End-to-End solution, with a great product availability, product diversity, vendor choice, significant market lead, being on the state-of-the-art and updated upon the latest technology.

4. A PROPOSED APPROACH FOR ROADMAP DESIGN

As mentioned before, the current work continues from results obtained in the previous roadmap work. Following **Figure 3** represents the roadmap approach in ICT4E2B Forum. The gray items represent external contributions beyond the consortium.

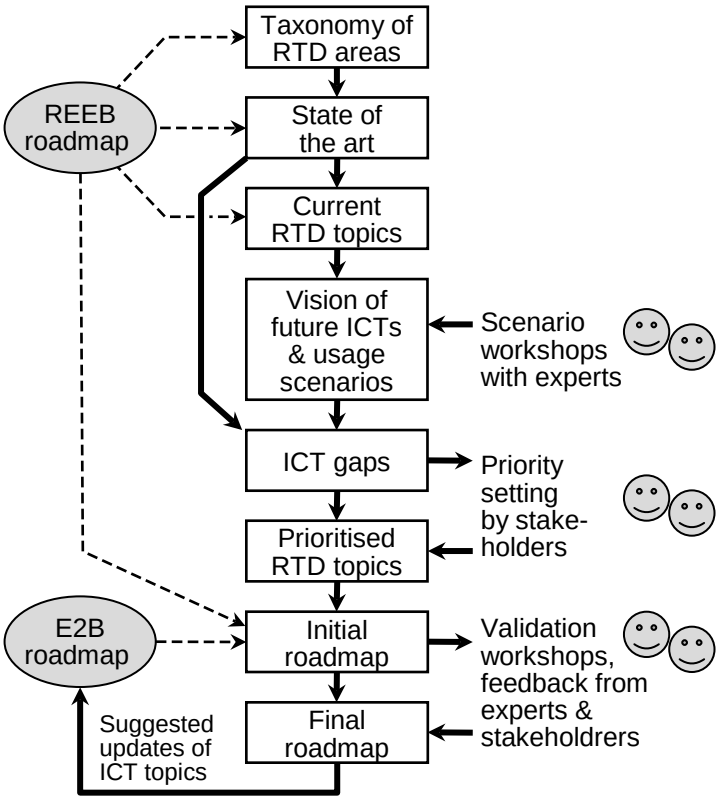

Figure 3: Summary of the Roadmap Approach

REEB roadmap: The ICT4E2B Forum project engages experts and stakeholders from the ICT, construction and energy sectors to update and validate the Research and Technology Development (RTD) roadmap that was issued by the REEB project in October 2010.
E2B roadmap: This roadmap was prepared by the E2B Association in 2009. It broadly addresses RTD priorities for construction. The ICT topics were mainly provided the partners of the REEB project which was then ongoing. ICT4E2B Forum will suggest updates to the roadmap.
Taxonomy of RTD areas: Classification of research areas into five main categories (**Table 2**), each divided into three to four subcategories. The taxonomy is essentially unchanged from REEB.

Main category	Subcategory
1. Tools for integrated design and production	☐ Design ☐ Production management ☐ Modelling ☐ Performance estimation
2. Intelligent & Integrated Control	☐ Automation & control ☐ Monitoring ☐ Quality of service ☐ Wireless sensor networks
3. User awareness & decision support	☐ Performance management ☐ Visualisation of energy use ☐ Behavioural change
4. Energy management & trading	☐ Building energy management ☐ District energy management ☐ Smart grids and the built environment
5. Integration technologies	☐ Process integration ☐ System integration ☐ Knowledge sharing ☐ Interoperability & standards

Table 2: Identified five main categories and related subcategories

The roadmap is being developed through following eight steps:
State-of-the-art: Identification of ICT solutions that are already been used by the industry and main results from recently completed research.
Current RTD topics: Topics and main expected results of currently ongoing research. Up to 100 European and national initiatives are analyzed.
Vision of future ICTs & usage scenarios: Extrapolation of future ICTs beyond the state-of-the-art based on current research, industry needs and ICT trends. Visionary stories how new ICTs could be used in 2010 and beyond. Scenarios are developed with external experts in workshops using template presented in **Figure 4**.

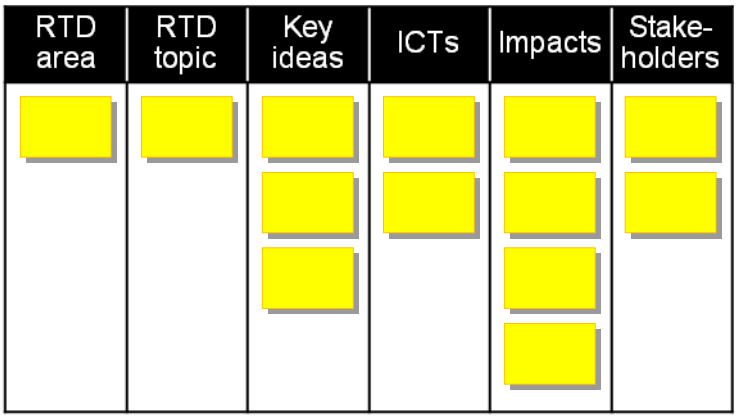

Figure 4 Template used for scenario work

ICT gaps: Identification of required progress from the state-of-the-art to the envisioned future ICT.
Prioritized RTD topics: The vision and gap analysis is presented to experts and stakeholders. They are offered the possibility to prioritize the topics at workshops and via polls, questionnaires and discussions on the web forum.
Initial roadmap: The initial roadmap is based on the REEB roadmap. Prioritized RTD topics in short, medium and long term are highlighted and further elaborated.
Final roadmap: The roadmap is finalized based on validation workshops with experts and feedback from stakeholders. Recommendations will be made to update the ICT-related topics of the E2B roadmap accordingly.

5. CONCLUSION

ICT4E2B Forum project aims to produce a technology roadmap on ICT for Energy Efficient Buildings able to show a clear, shared and agreed vision of the different stakeholder involved in the whole value chain. In this paper the relevant reference elements and the proposed approach to reach the final goal of the project are presented.

REEB project results are relevant since they consider all the relevant issues coming from the technical stakeholders in the different fields involved in the topic of ICT for Energy Efficient Buildings. Together with an updated review of the Industrial State-of-the-Art they represent the baseline for the next activities of the project.

Starting from this reference base, the proposed methodology has been designed to actively involve relevant stakeholders in all the relevant phases of the process, they will be involved in fact by providing their vision and prioritization during the set-up of the roadmap, but also providing a continuous assessment of the project results during the iterative process of roadmap updating.

The final ICT4E2B Forum shall therefore provide a high-level and wide-horizon vision of what will be the future challenges of research and technology development in ICT for Energy Efficient Buildings and what will be the most effective instruments to tackle these challenges.

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