



ICT Supported Energy Efficiency in Construction

Strategic Research Roadmap and Implementation Recommendations



Design & Production Management

Intelligent & Integrated Control

User Awareness & Decision Support

Energy Management & Trading

Integration Technologies

Short Term

Meeting Energy Efficiency Requirements

Medium Term

Lifecycle Optimised Energy Efficiency Performance

Long Term

Business Models Driven by Energy Efficiency

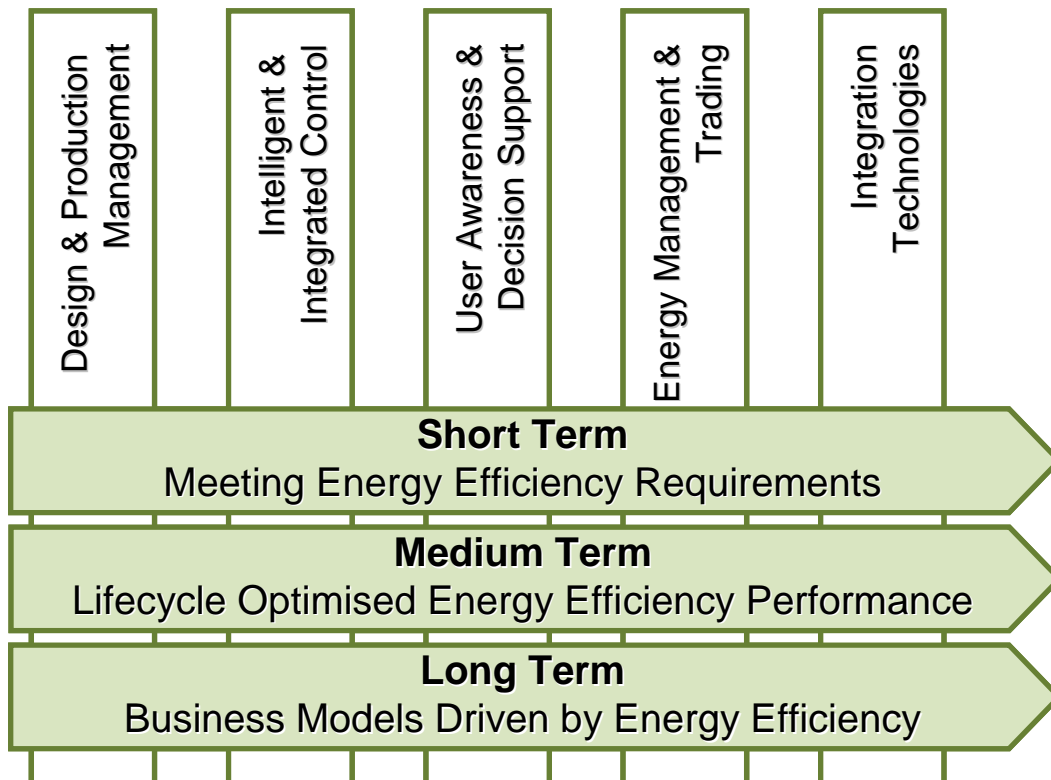
ISBN 978-951-38-7432-2





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Strategic Research Roadmap and Implementation Recommendations



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ISBN 978-951-38-7432-2

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ICT Supported Energy Efficiency in Construction

Strategic Research Roadmap and Implementation Recommendations

Most energy usage of buildings throughout their life cycle is during the operational stage (~80%). The decisions made in the conception and design stages of new buildings, as well as in renovation stages of existing buildings, influence about 80% of the total life cycle energy consumption. The impact of user behaviour and real-time control is in the range of 20%. ICT has been identified as one possible means to design, optimize, regulate and control energy use within existing and future (smart) buildings.



This book presents a collection of best practices, gap analysis of current research and technology development activities, a research roadmap, and a series of recommendations for ICT supported energy efficiency in buildings. Key research, technology, and development priorities include: integrated design and production management; intelligent and integrated control; user awareness and decision support; energy management and trading; integration Technologies.



The vision for ICT supported energy efficiency of buildings in the short, medium, and long term is advocated as follows:

- Short term:** Buildings meet the energy efficiency requirements of regulations and users
- Medium term:** The energy performance of buildings is optimised considering the whole life cycle
- Long term:** New business models are driven by energy efficient “prosumer” buildings at district level – long term.



Foreword

The work presented in this book has been both highly encouraged and supported by the public statements made by various key stakeholders and decision makers. Some of these statements are presented here:

ICT for Energy Efficiency 2010, 23-24 February, 2010, Brussels

(webcast.ec.europa.eu/eutv/portal/archive.html?viewConference=8511&catId=8484)

- ICT will make households be able to: monitor their energy consumption; adapt to tariff changes; control loads by scheduling ons and offs of their plug loads; ... and change their behaviour. *Christian Kornevall. Director, World Business Council for Sustainable Development (WBCSD)*
- ICT can do a lot for decentralizing EU energy market but also to improve coordination of actors. *Claire Roumet. General Secretary, CECODHAS*
- The convergence of IT and Building Technologies provides data-focused services to reduce building energy and emissions up to 40%. *Oliver Guillaumond. Senior Manager, Accenture Sustainability Services*
- Building automation and controls are most effective to enable energy savings in the building sector. Technical building equipment and controls have an average payback period shorter than 10 years. Insulations, windows, etc have an average payback period longer than 10 years. *Jean-Yves Blanc. Senior Vice President, Building Automation Strategy, Schneider Electric*
- Energy efficient building usage requires continual optimization and monitoring. *Sabrina Soussan. Global Head of Marketing for Building Automation, Siemens Schweiz AG*
- ICT in service of buildings energy efficiency may be also used in a way to inform users and make them aware of the importance of their particular actions. This approach aims at control the dynamic of energy demand in buildings. Estimated reduction could be 25% of energy use. *Juliusz Zach. Head of Energy Group R&D Department, Mostostal, Warszawa*
- We think of a Smart Grid as a self monitoring system, based on industry standards, that provides a stable, secure, efficient and environmentally sound network. *Tamara Schenk. Head of Special ICT Innovation Projects, T-Systems International GmbH*
- Energy Distribution must become more 'active', i.e. more Transmission-like, giving big opportunities for the ICTs. *Jorge Esteves. Director of the Infrastructures and Networks Division, ERSE-Portuguese energy regulatory authority*
- The term Smart Grid (intelligent energy distribution system) comprises the networking and control of intelligent generation, storage, consumers and interconnected elements of energy distribution and transmission systems by the means of ICT. *Mathias Uslar. Forschung und Entwicklung Bereich Energie, OFFIS*
- In order to maximize the benefits, the Smart Grid must ensure that there are levels of interoperability among sensors, devices and information systems. *Gisele Widdershoven. Senior Consultant Smart metering, KEMA Consulting*

Statements from Key Stakeholders' Websites

- Buildings consume 40% of the total energy and 72% of the total electricity in the US, with much of it being wasted. There's a huge opportunity to improve this via computer-based management. *Eco-Sense Buildings – Innovation@Intel*, (www.intel.com/pressroom/innovation/innovation.htm)
- The fastest and least expensive way to lower energy usage is to optimize the building's insulation and windows for energy efficiency and put in sensors, which can turn off lights and monitor air quality. ... Knowing when and where energy is consumed reduces peak usage and offers more flexibility in meeting utility company demand-response program. *Cisco Energy Management Solution*. (www.cisco.com/web/strategy/docs/gov/CiscoGovernmentEnergyManagement_AAG_D11.pdf)
- Commercial and residential buildings account for about 38 percent of global end-user energy demand, mainly for heating, cooling and powering electric appliances. Adjusting the heating temperature, lighting and the energy consumption of electric appliances to the actual requirements offers a substantial energy-saving potential without compromising comfort or quality of life. *ABB efficiency from power plant to plug*. (<http://www.abb.com/cawp/db0003db002698/29f81c7688243936c12571e1000bb2f8.aspx>)
- Over 80 percent of the costs for a structure are incurred in the actual usage phase. Any additional costs for energy-efficient planning and construction have usually been amortized within just a few years.” *Green Building - Sustainable Planning and Building – Nemetschek* (http://www.nemetschek.com/en/greenbuilding/green_solutions.html)

Executive Summary

Buildings are responsible for at least 40% of energy use in Europe, due to heating and lighting operations. Moreover, buildings are the largest source of CO₂ emissions in the EU. According to Smart2020, the worldwide energy consumption for buildings will grow by 45% from 2002 to 2025 – where buildings account for about 40% of energy demand with 33% in commercial buildings and even 67% in residential buildings.

Most energy usage of buildings throughout their life cycle is during the operational stage (~80%). The decisions made in the conception and design stages of new buildings, as well as in renovation stages of existing buildings, influence about 80% of the total life cycle energy consumption. The impact of user behavior and real-time control is in the range of 20%. ICT has been identified as one possible means to design, optimize, regulate and control energy use within existing and future (smart) buildings.

This book presents some of the key findings from the REEB project (European strategic research Roadmap to ICT enabled Energy-Efficiency in Buildings and constructions). REEB was launched to identify the current state of research, best practices, and provide a vision in the form of a strategic research (roadmap) agenda with supporting implementation recommendations for ICT supported energy efficiency in construction. The content of this book covers the state of the art and best practices, a gap analysis of research and technology development initiatives, structured roadmaps based on industrial priorities, and a series of recommendations.

The REEB vision for ICT supported energy efficiency of buildings in the short, medium, and long term can be summarized as follows:

- Buildings meet the energy efficiency requirements of regulations and users – short term.
- The energy performance of buildings is optimised considering the whole life cycle – medium term.
- New business models are driven by energy efficient “prosumer” buildings at district level – long term.

It is advocated that full exploitation of the opportunities offered by ICT for energy efficiency requires adjustments of the processes and contractual practices of the construction sector. The core is a transformation of focus from the initial construction cost to whole life performance i.e. value to owners, especially with regard to energy performance.

The REEB project developed 12 key best practices based on an evaluation of more than 80 case studies. These best practices cover: simulation based energy design; early energy design; integrated modelling solutions based on BIM; 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; websites for collecting and disseminating energy-efficiency “good practices”; smart grids; standards-based solutions for building life-cycle management; and standards-based energy data exchange solutions.

During gap analysis of research and development initiatives, five main priority areas (categories) of research were identified based on a review of more than 270 relevant projects of which 52 were deeply analyzed. The identified priority areas were: Integrated design and production management; Intelligent and integrated control; User awareness and decision support; Energy management & trading; and; Integration technologies.

For each of these five priority areas, detailed roadmaps were developed. These roadmaps covered a (sub-)vision, drivers, barriers, impacts, key business scenarios, and short, medium, and long term priorities.

To guide towards realisation of the actions identified in the roadmaps, several implementation actions were recommended 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.
- Research and technology development: tools 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.
- Education and training.

Implementation of these recommended actions are 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.

The REEB project together with its special interest group members and its extensive international REEB community has provided a set of industrial best practices, and most importantly a series of roadmaps and supporting implementation actions for ICT supported energy efficiency in buildings. These have been validated by key stakeholders from both ICT and construction sectors. There is a need however to extend this to a much larger stakeholder forum for proper take-up 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) project. The main aim of ICT4E2B is to bring together all relevant stakeholders involved in ICT systems and solutions for Energy Efficiency in Buildings, at identifying and reviewing the needs in terms of research and systems integration as well as at accelerating implementation and take-up. This is a natural follow-up to the work presented in this book and is expected to serve as a basis for further validation, renewal, acceptance, and implementation of the research roadmap and implementation recommendations that are presented here-in.

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Preface

Background and Context

In the field of energy efficiency, buildings are significant consumers of energy. Although various and numerous control solutions have been deployed already in many commercial buildings, these remain often standalone and proprietary legacy systems. The new sustainable challenges that buildings have to face today (including but not only improved energy-efficiency), foster the development of new technologies and new solutions which will drastically change our future built environment.

In this context, ICT becomes an essential asset. The convergence of technologies on one side, and environmental regulatory drivers on another side, offers unprecedented technical and business opportunities for powerful innovations to be integrated in new and existing buildings. The related technologies especially include embedded systems, standardised and interoperable communication protocols, Smart Grid and Internet applications. An acknowledged vision today considers future buildings along with their components and environment providing information on their status. This information will be interoperable via common protocols for holistic automation and control. In the energy domain, the whole building will be supervised by intelligent systems that should holistically control all sub-systems, components and equipments thanks to advanced control algorithms. Indeed, it will be able to combine information from all connected devices, from the Internet and from energy service providers to efficiently control HVAC (heating, cooling & ventilation), lighting and domestic hot water systems. This will be done along with energy production, storage and consumption devices inside the building taking into account the users' needs and preferences. ICT is recognised as key for empowering people with both smart e-metering and new smart e-devices. It is highly expected that ICT becomes fully pervasive in the future optimization of energy in the built environment where energy-efficient smart buildings are to be buildings with information management for an optimal energy flow over its lifecycle.

The REEB coordination action (*European strategic research roadmap to ICT enabled Energy-Efficiency (EE) in Building and Construction*), as a European (EC-funded) R&D technology roadmap initiative, has been set to develop a European-wide agreed vision and roadmap on ICT contributions to improve the energy efficiency of buildings, providing pathways to accelerate the research, development, experimentation, adoption, and take-up of emerging and new technologies that may radically transform buildings and their associated services in terms of enhanced energy consumption.

The ultimate objective is to put ICT at the core of the energy efficiency effort and to enable reaching their full potential, making necessary to foster R&D into novel ICT-based solutions and strengthen their deployment and take-up — so that the energy demand of buildings can be further reduced by adding intelligence to components, equipment and services. In order to achieve it, REEB has studied improvement (and corresponding RTD) in integrated ICT tools for:

- Integrated EE design and production management;
- Integrated and intelligent control;
- User awareness and decision support to various stakeholders throughout the whole life of buildings;
- Energy management and trading;
- Integrated systems and solutions for EE.

Approach and Structure

This book summarizes a series of continued work for the development of the Project Vision and Roadmap. The project has identified a common taxonomy for a broad coverage of the scope of ICT4EEB (Information and Communications Technologies for Energy Efficient Buildings) domain, harmonizing the work within the project and to present the project results in a consistent way. In order to align with the industry’s priorities the REEB project presents its results organized into corresponding categories of research topics:

1. Tools for EE design and production management
2. Intelligent control
3. User awareness and decision support
4. Energy management and trading
5. Integration technologies

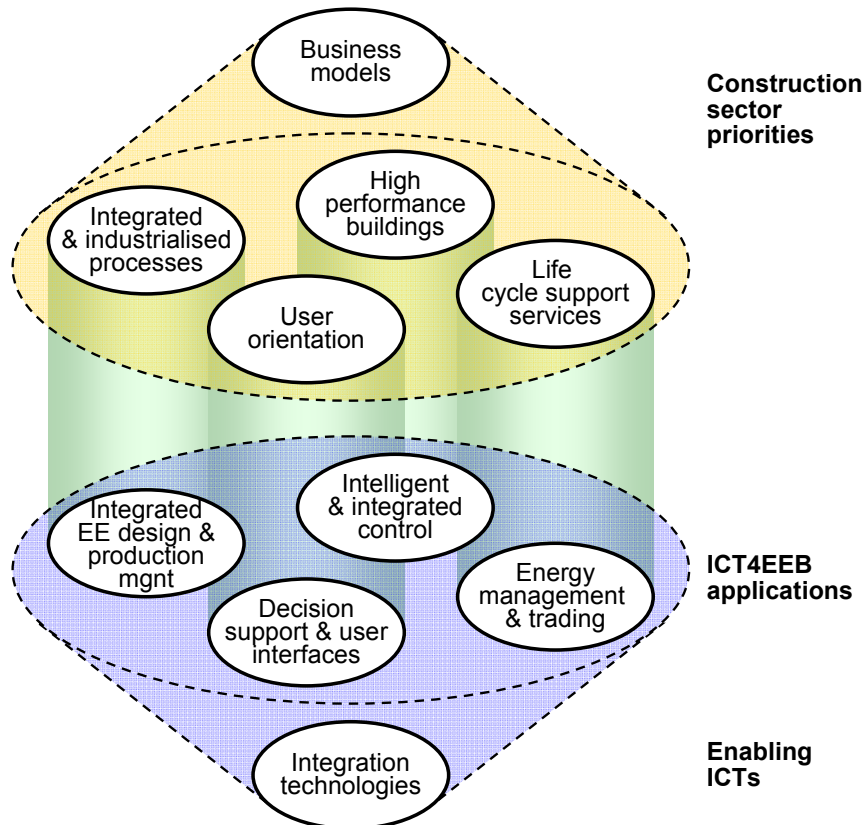


Figure 1: Mapping of construction sector priorities and ICT4EEB

These RTD priorities should be expressed at various time spans:

- **Short term:** Assuring compliance to regulated minimum energy performance levels in design and renovation stages.
- **Medium term:** Decision support for life cycle cost/performance optimization. Real time operation, control and user empowerment.
- **Long term:** Holistic optimization of built environments considering: energy generation and usage of individual buildings, energy balancing between buildings within a district, responding to grid load and feeding excess energy into the grid. New business models driven by whole life time performance.

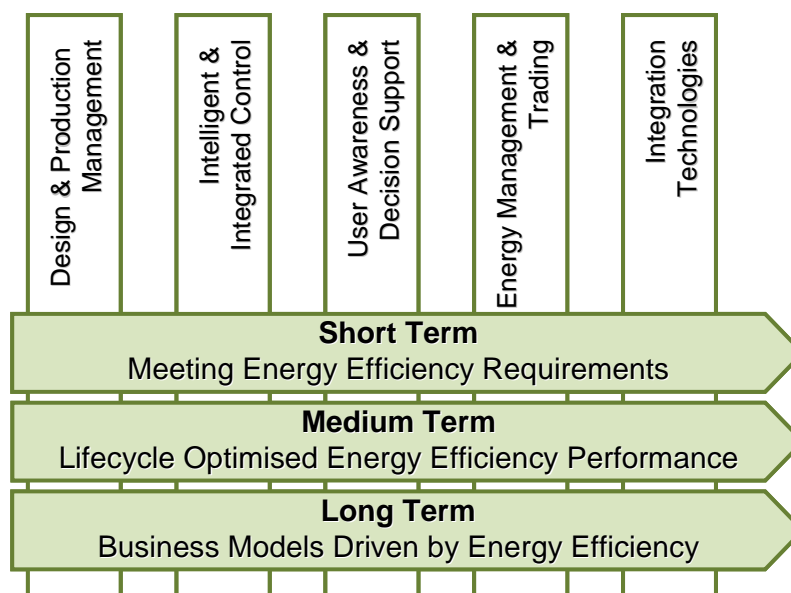


Figure 2: RTD priorities for different time spans

The establishment of this baseline of current facts, trends and issues as a planning scenario and modelling approaches to assess the prioritized needed actions to affect the energy efficient in buildings through ICT systems has the aim to increasing the visibility and improve the understanding of the current and potential impact of ICTs as an enabler for energy efficiency in buildings: through various communities of stakeholders (industry, academia and research institutes, consumers, etc) getting involved and working together. To this end, the process focuses on: Promoting interoperability among solutions and standardization work; coordinating awareness raising and sharing of best practices; advising on operational details, the effects of regulation and the impact of energy efficiency and encouraging the production of RTD roadmaps and identifying RTD priorities.

It is expected that the path of energy productivity growth can continue while leading the global effort to tackle climate change and energy efficiency, improving the potential of ICTs in EE focusing on the most promising domains (the power grid, smart buildings, smart lighting and ICT itself) through exchange of best practices, reinforce of RTD, take-up promotion and foster demand-driven innovation. Special attention should be paid to urban areas, which represent a particular challenge in this context and can provide the right setting for testing, validating and deploying ICT-based solutions. It is the aim to facilitate increasingly closer cooperation among all stakeholders with to unlock the potential of ICTs to improve energy efficiency, thereby promoting the competitiveness of European industry, creating a wealth of opportunities, jobs and services and building to benefit industry, users, and society at large.

Work in the REEB project has focused on ICT supporting energy efficiency in buildings forming part of a short, medium and long-term agenda. It is expected a persuasive result not only in reference to improvement of energy efficiency and climate change but also to stimulate the development of a large leading-edge market for ICT enabled energy-efficiency technologies in buildings that will foster the competitiveness of European industry and create new business opportunities. It is important to achieve the best possible ICT impact expecting the results in knowledge, infrastructure– networks, devices, services – as well as in the market structures, value chains and business models. Progress must be made through more functionality and performance at lower cost as well as better adaptability and learning capabilities of ICT systems to facilitate user control; including stronger requirements for reliability and security of ICTs and the need to handle higher volumes and more complex digital content and services.

Content Portfolio

This book is structured in the form of five main sections. These sections cover the Vision for ICT-enabled energy efficiency of buildings; Best Practices drawn from a thorough understanding of the current state-of-the art and practice; Gap Analysis of Research and Development Activities; Roadmap(s) for integrated design and production, intelligent control, user awareness and decision support, energy management and trading, and integration technologies; and Recommendations for research and development, policies, coordination, take-up, standardisation, and, education and training.

Vision

It is advocated that ICT will contribute to the energy efficiency of buildings mainly via design tools, automation & control systems and decision support for various stakeholders:

- Short term: ICT will be used to ensure that existing and new buildings meet the current and emerging requirements for energy efficiency.
- Medium term: ICT tools will enable life cycle optimised design and energy management during operation.
- Long term: ICT will enable and support new business models and processes driven by energy efficiency. Buildings have evolved from energy consumers to “prosumers” (producer + consumer).

Best Practices

A total of twelve main best practices are presented. These are the outcome of a thorough analysis, clustering and consolidation of more than eighty different state-of-the-art and practice examples collected from more than fifty individual contributors. The twelve presented generic best practices cover:

- Simulation based energy design
- Early energy design
- Integrated modelling solution based on BIM (building information modelling)
- Smart metering for energy consumption awareness
- Building management systems
- Wireless sensor networks for energy performance assessment software
- Standards-based energy performance assessment software
- Energy performance audit solutions
- Websites for collecting and disseminating energy-efficiency “good practices”
- Smart Grids
- Standards-based solutions for building life-cycle management
- Standards-based energy data exchange solutions

Gap Analysis of Research & Technology Development Activities

To gather a better understanding of the current state of research and gap analysis of research and technology development (RTD) activities specific to ICT usage for Energy Efficiency (EE) in Buildings, a total of two hundred and seventy projects were reviewed. Of these, fifty two were detailed analysis and development of main classification category and corresponding sub-category definition and analysis. The main categories served as the basis for structuring the work within the REEB project. These main categories were:

- Energy Efficient (EE) design & production management;
- Intelligent & integrated control;
- User awareness & decision support;
- Energy management & trading;
- Integration Technologies.

Key research challenges for each of the main categories are presented and are addressed in the roadmap(s).

Roadmap

Five main roadmaps corresponding to the main five categories are presented. These roadmaps cover visions, key research topics, drivers, barriers, impacts, key business scenarios, and short, medium, and long term priorities. The following roadmaps and corresponding sub-topics (categories) considered are illustrated below:

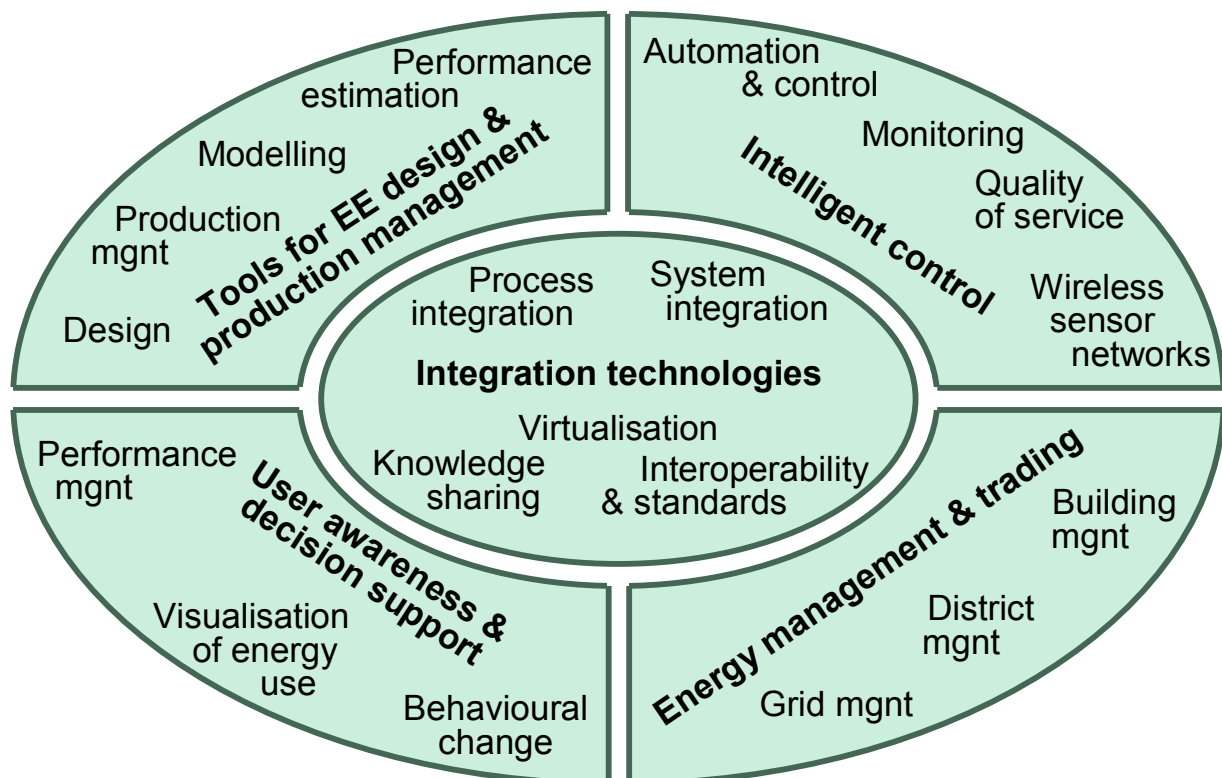


Figure 3: RTD priorities for ICT enabled energy efficiency in buildings

Recommendations

To guide towards realisation of the actions identified in the roadmaps, several recommended implementation actions are presented. These cover:

- 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.
- Research and technology development: tools 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.
- Education and training.

Acknowledgements

The work presented in this book is a consolidation of the contributions of numerous organisations and individuals that have contributed in the development, analysis, validation, and review of the results presented. We would like to acknowledge the hard work and support of all these individuals and organisations.

Members of the REEB consortium who actively contributed include:

- Centre Scientifique et Technique du Bâtiment (France): Alain Zarli, Marc Bourdeau, Regis Decorme
- VTT Technical Research Centre of Finland (Finland): Matti Hannus, Abdul Samad (Sami) Kazi, Veijo Lappalainen, Mia Ala-Juusela
- Commissariat a l'Energie Atomique (France): Philippe Marechal, Jean Louis Six, David Corgier
- Technalia (Spain): Juan Perez, Borja Tellado
- Acciona Infraestructuras (Spain): Javier de las Heras, Rafael Socorro, Jose Luis Buron Martinez
- Arup Group Ltd. (UK): Marta Fernandez, Kin Puan Wong, Jeremy Watson
- University College Cork (Ireland): Karsten Menzel, Andriy Hryshchenko
- Technische Universität Dresden (Germany): Raimar Scherer, Tatiana Suarez, Peter Katranushkov, Thomas Eisenreich

Members of the REEB Special Interest Group (SIG) were active contributors to and reviewers for the key outputs of the project. These included:

- Gradbeni institut (Slovenia): Marjana Sijanec Zavrl
- Loughborough University (UK): Tarek Hassan
- Danish Building Research Institute, Aalborg University (Denmark): Kresten Storgaard
- Schüco Service GmbH (Germany): Christian Glatte, Jörg Teunissen
- Electricite de France SA (France): Dominique Feldmann
- D'Appolonia spa (Italy): Giorgio Pezzuto
- Philips Technologie GmbH Philips Research (Germany): Peter Fuhrmann
- Bouygues Construction (France): Claude Lenglet
- Iberdrola Inmobiliaria S.A.U. (Spain): Carlos Bello
- AGSAVING SRL (Italy): Alfio Galatá
- Agencia Andaluza de la Energía (Spain): Joaquín Villar Rodriguez
- AGORIA (Belgium): Freddy Vandaele

The international REEB community was very active in reviewing the outcomes of the project and in providing valuable insights into new trends, suggestions for research topics and ideas specific to ICT for Energy Efficient Buildings. In particular, we would like to acknowledge the contributions of the following:

- Agoria – Freddy Vandaele
- Agsaving – Alfio Galatà
- Andalusian Energy Agency – Francisco Arévalo García
- Austrian Energy Agency – Susanne Geissler
- Austrian Institute of Technology - Gerhard Zucker
- D’Appolonia S.p.A. – Thomas Messervey, Stefano Carosio
- ENEA – Alberto Moro
- ESI-Tecnalia - Huascar Espinoza
- Fraunhofer IAO / IAT University of Stuttgart – Sven Schimpf
- Honeywell – Petr Stluka
- IBM – Joe Potter
- Iberdrola Real Estate – Carlos Bello
- IBM – Xavier Vasques, Herve Rey, Richard Lanyon-Hogg
- ISA, Intelligent Sensing Anywhere, SA – Nuno Martins
- Loughborough University – Tarek Hassan
- Orange Labs – Gilles Privat
- PassivSystems Ltd – Colin Calder
- Teesside University – Nash Dawood, Tracey Crosbie
- Tyndall National Institute / University College Cork – Nicolas Cordero, Michael Hayes

The REEB project has benefited from the kind financial contribution of the European Commission through its ICT programme. This contribution is acknowledged along with the continuous feedback the REEB consortium received on the content of its outputs.

The results of REEB will be further shared, validated, updated, and consensus on implementation of the same sought through the ICT4E2B Forum project (<http://www.ict4e2b.eu/>). This project is the natural successor to REEB, and we sincerely hope you will engage with it for ideas and inspiration, and share your contributions on ICT for Energy Efficient Buildings.

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Vision

Vision

Context - Energy Usage in Buildings

Most energy usage of buildings throughout their life cycle is during the operational stage (~80%). The decisions made in the conception and design stages of new buildings, as well as in renovation stages of existing buildings, influence about 80% of the total life cycle energy consumption. The impact of user behaviour and real-time control is in the range of 20%.

Currently the energy performance of buildings is mainly driven by regulations. The prevailing market practice is driven by initial investment cost with little attention to life cycle costs. The awareness of energy efficiency is raising business incentives towards sustainable solutions beyond the required minimum level.

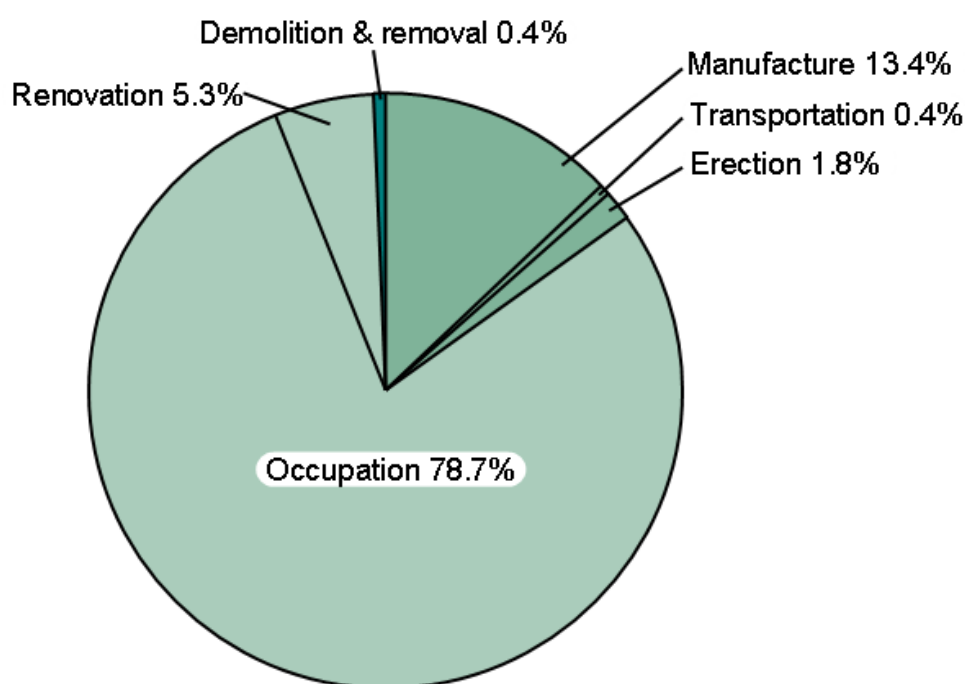


Figure 4: Energy use during the lifecycle of a building *

Most of the energy consumed by a building throughout its life cycle is consumed during its operational stage. The decisions that influence energy consumption are mainly made in the design stage and also in (repeated) renovations. Altogether, many stakeholders, parallel processes and life cycle stages are involved.

* Bozdağ, Ö & Seçer, M. Energy consumption of RC buildings during their life cycle. In: Sustainable construction, materials and practices (SB07). ISBN 978-1-58603-785-7. Pp. 480-487. 2007

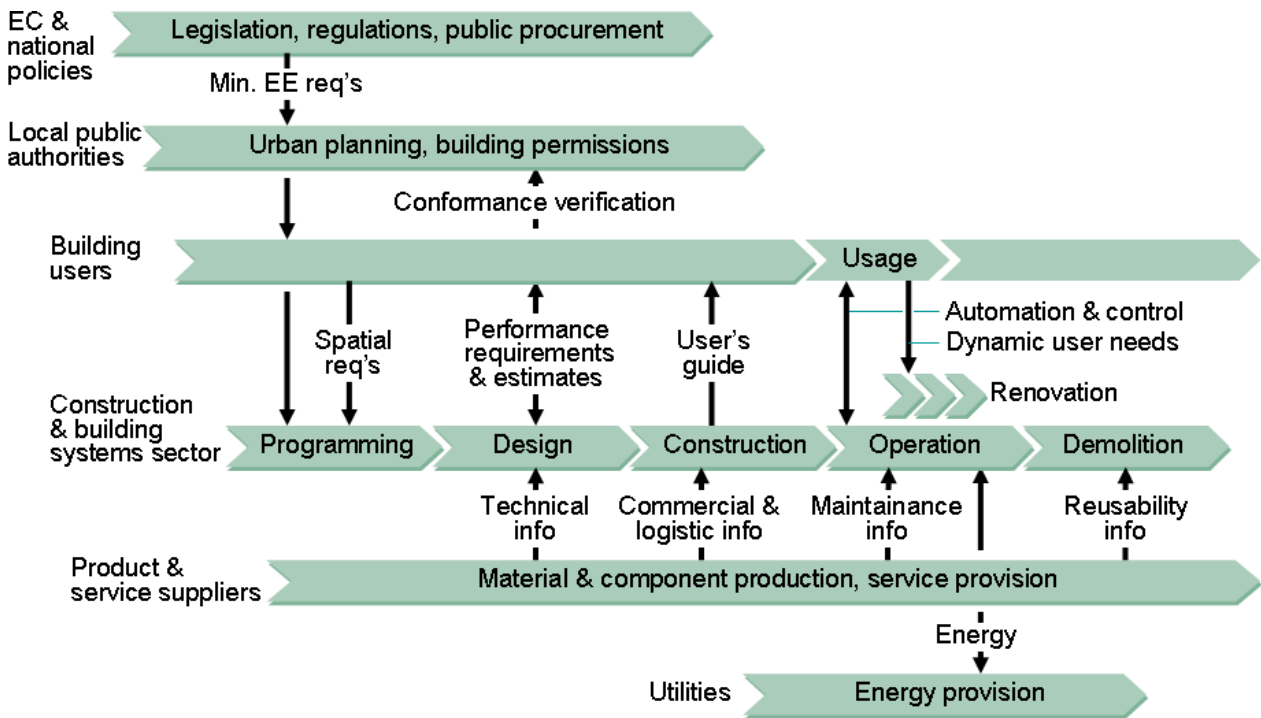
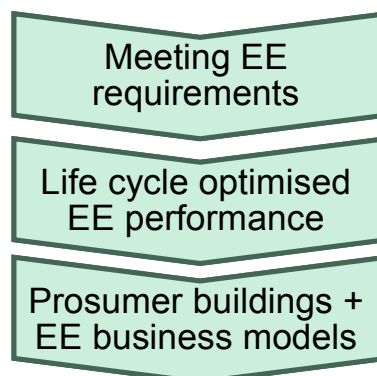


Figure 5: Context of energy use in buildings

Vision – ICT enabled Energy Efficiency of Buildings

ICT will contribute to the energy efficiency of buildings mainly via design tools, automation & control systems and decision support for various stakeholders:

- **Short term:** ICT will be used to ensure that existing and new buildings meet the current and emerging requirements for energy efficiency.
- **Medium term:** ICT tools will enable life cycle optimised design and energy management during operation.
- **Long term:** ICT will enable and support new business models and processes driven by energy efficiency. Buildings have evolved from energy consumers to “prosumers” (producer + consumer).



Vision of ICT enabled energy efficiency in short, medium and long term

Priority Areas in ICT for Energy Efficiency in Buildings

ICT is often perceived by practitioners as various specific computing and automation applications. However, ICT is also a generic enabler for integration of various processes, applications, systems and technologies: databases, collaboration & communication infrastructures, interoperability standards, knowledge management, modelling, optimisation, simulation, visualisation, etc.

There are five key research areas where ICT enables both new applications and integration, as illustrated below:

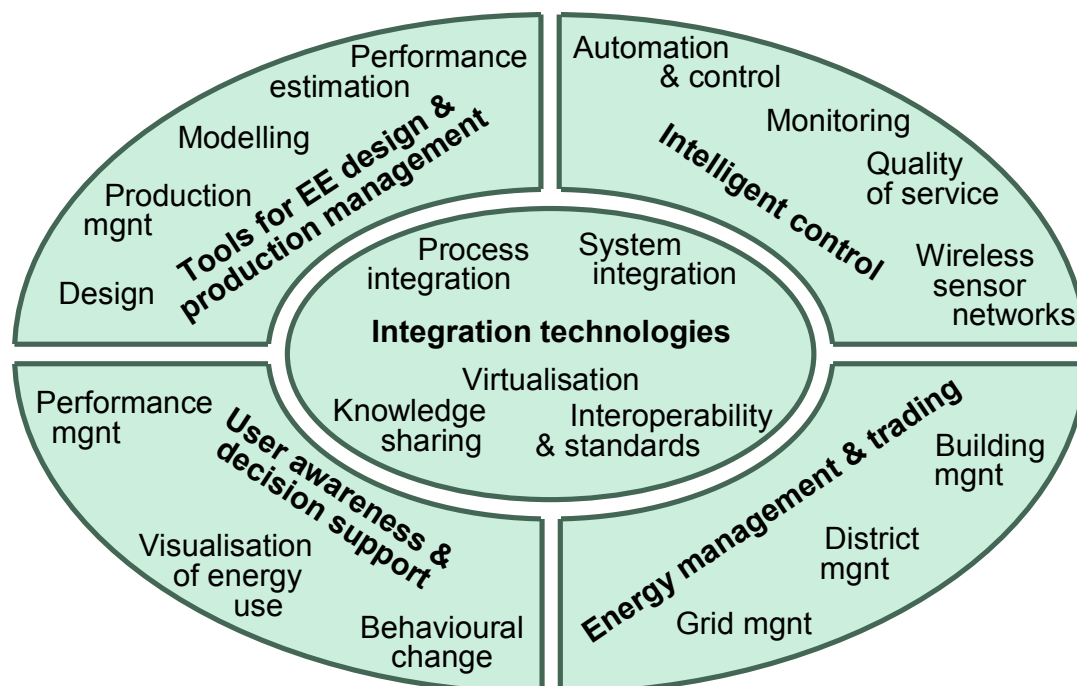


Figure 6: Priority areas in ICT for energy efficient buildings

The role of ICT in these areas is envisaged 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, and 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.

ICT support for Lifecycle Stages

ICT is expected to provide support for all building lifecycle stages. Three generic lifecycle stages are considered:

- Definition – programming, conception, design;
- Realisation – planning, production, manufacturing, procurement, assembly;
- Usage – facility management, operation, maintenance.

Definition stage – programming, conception, design

- Requirement management: capturing user/client requirements and formalising them into measurable indicators. Performance assessment and compliance verification methods.
- Catalogues of materials, components, connections, interfaces. Configuration design tools. Design for constructability.
- Applications for analysis, design, optimisation, simulation, visualisation, virtual & augmented reality and decisions support.
- Design methodologies for system integration, energy efficiency and operability.
- Standards for exchanging and sharing building information models (BIMs).
- Integrated design environments. Communication & teamwork support applications and platforms.
- Catalogues of re-usable knowledge, guidelines and best practices. Configuration tools to customise solutions from “templates”.
- Value proposition/branding supported by verifiable methods to assess, simulate & visualise product performance for decision making and contracting.
- Regulation data bases and automatic code compliance checking tools.

Realisation stage – planning, production, manufacturing, procurement, assembly

- Translation of performance requirements to all stakeholders in the supply network and verifying compliance.
- Off-site manufacturing of components and modules. Manufacturing automation. Industrialised methods on-site production & renovation. Applications for constructability assessment, scheduling & planning. Recording as-built model. Tagging (e.g. RFID) and tracing of materials, products, equipment, vehicles etc. Site access control. Quality control. Ambient production status information e.g. via mobile user interfaces. On-line construction site.
- E-business platforms. Standards for technical and commercial information about products & services.
- Logistics & supply network management. Integrated project management environments.
- Catalogues of products, services and suppliers.
- Integration of value & supply chain. New financial & contractual models for value driven delivery. Handling of IPR of digital information.

Usage stage

- Monitoring of actual performance and verifying compliance to requirements. Smart metering. Feedback on energy consumption to users.
- “Industrialised” service provision.
- Recording as-used model. Facility management applications. Integration of BIM with real time information (e.g. simulation based predictive control).
- Embedded intelligence: sensors, actuators, wireless networks. Automation & control. Monitoring of the condition and status of materials, components & systems. Integration of various smart systems (e.g. access control and energy management).
- Standards for automation and control protocols, interfaces and gateways.
- Platforms and gateways for integration of ambient services. Virtualisation of living & working environments.
- Adaptive and self-learning systems. Platforms/forums for benchmarking the performance of buildings.
- Integrated services for operation, monitoring, maintenance, (energy) management at building and district levels.
- Predictive maintenance of installations and Renewable Energy Sources (RES).

ICT-enabled Business Opportunities

ICT is a key enabler for energy efficiency driven new business models in construction. Synergies and co-operation between construction, energy and ICT companies will enable a new range of business models where innovative local and regional small and medium enterprises will play a key role. New business models will overcome the non-technological barriers that discourage innovation and market deployment. The contractual and financial conditions provide incentives to all stakeholders towards life-cycle optimised buildings.

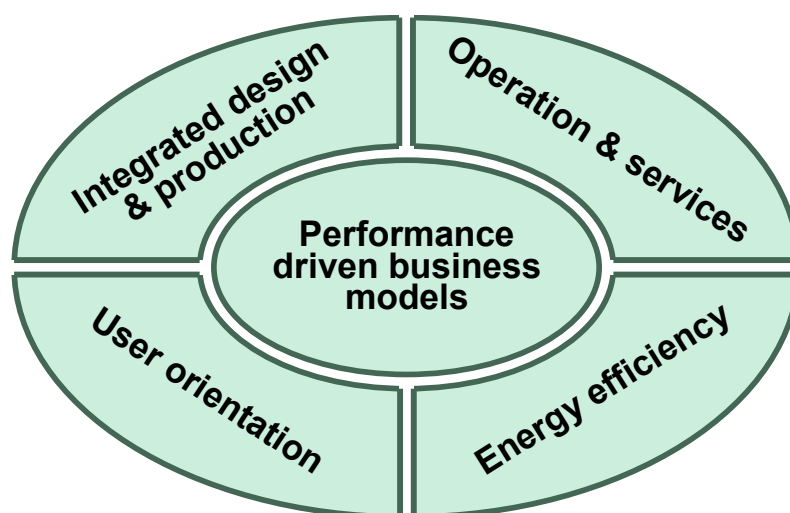


Figure 7: Construction sector priorities - the main drivers for ICT use

Some examples of the new business opportunities that will be realised based on ICT-enabled energy efficient buildings are:

- System and service integration: Integrating offerings from different vendors, companies will offer integrated solutions.
- User-customisable energy efficient design: The client is able to select and customise his future building selecting generic components from a given catalogue. For each component, it is possible to analyse the energy consumption figures of the whole building not only during the operation phase but also taking into account embodied energy of each material so that he is able to select the most efficient solution.
- Innovative Building-technology products and electrical devices: dealing with more energy efficient space-heating, HVAC equipments, elevators, water boilers, appliances, white goods, etc.
- Transparency-creating products: educating energy end users about the impact of their choices and behaviours on their energy consumption and therefore encouraging more conscious use of energy. These products will include smart meters and graphic user interfaces at the consumer's location.
- Remote operational services: The telecom provider plays an important role in the delivery of smart building applications to the end-user or to the utility providers. End-users are offered energy-efficiency applications using multimodal interactive interfaces (TV, PC, mobile phone, ...) e.g. smart metering details, real-time power consumption of appliances, temperature monitoring, etc. The utility company is offered smart metering services. In addition, the telecom provider enables maintenance of the BMS, and other services like remote monitoring, surveillance and management/control of appliances. ICT can empower people to remotely manage their vacation homes, enable technicians to manage many buildings from a central location thereby achieving scale and energy efficiencies (less commuting). The telecom provider is likely to play an important role in providing secure remote access to smart homes and buildings.

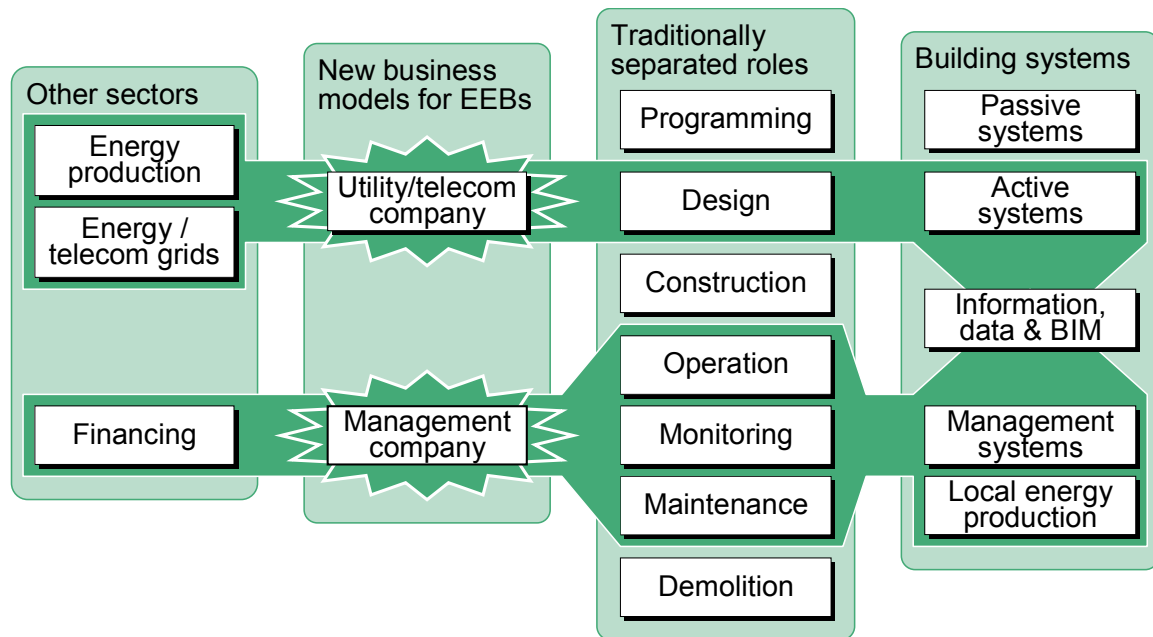


Figure 8: Examples of opportunities to new stakeholders involved in ICT-based Energy Efficient buildings business models

- Energy services: Energy Services Companies (ESCOs) will offer a wide range of activities to energy users, including operation and maintenance of installations, energy supply, often in the form of power and heat from co-generation, facility management (covering technical, cleaning, safety and security) and energy management including energy audits, consulting, demand monitoring and management.
- Holistic maintenance and operation services: Innovative companies provide remote predictive maintenance services of interoperable building-technology products and electrical devices such as energy production and storage, space-heating, HVAC equipments, elevators, water boilers, appliances, white goods as well other services like remote monitoring, surveillance and management/control of appliances. User is able to remotely manage their vacation homes, enable technicians to manage many buildings from a central location thereby achieving scale and energy efficiencies (less commuting).
- Local building energy trading: Within a district, prosumer buildings are trading the excess energy they produce but do not consume at a given time, enabling peak-shaving strategies. During the day, an office building buys energy from a residential house which is mostly empty at that moment. When the working day ends, the residential house is able to buy the spare energy produced by or accumulated by the office building.

Best Practices

Best Practices

A total of twelve generic best practices representative of the current state of the art / practice and beyond are presented. These best practices are the result of collection, analysis, clustering, and consolidation of more than eighty representative case examples collected from more than fifty contributors across Europe and internationally.

The methodology used to develop the twelve best practices was as follows:

- Using a dedicated form (the "BP description template") that was sent to relevant stakeholders, a large number of case studies describing exemplary uses of ICT applied to energy efficiency in buildings were collected. More than 100 people were contacted while about 50 different contributors provided more than 80 different examples.
- The collected case studies were then filtered and classified using 5 Main Classification Categories (Tools for energy efficient design and production management; intelligent control; user awareness and decision support; energy management and trading; integration technologies) and their respective subcategories.
- A detailed analysis of the collected case studies led to the identification of "clusters", or groups of case studies, that presented similarities in terms of applied concepts, technologies, or provided services.
- From the concepts, technologies and provided services appearing in the identified clusters, generic Best Practices were derived and further described.

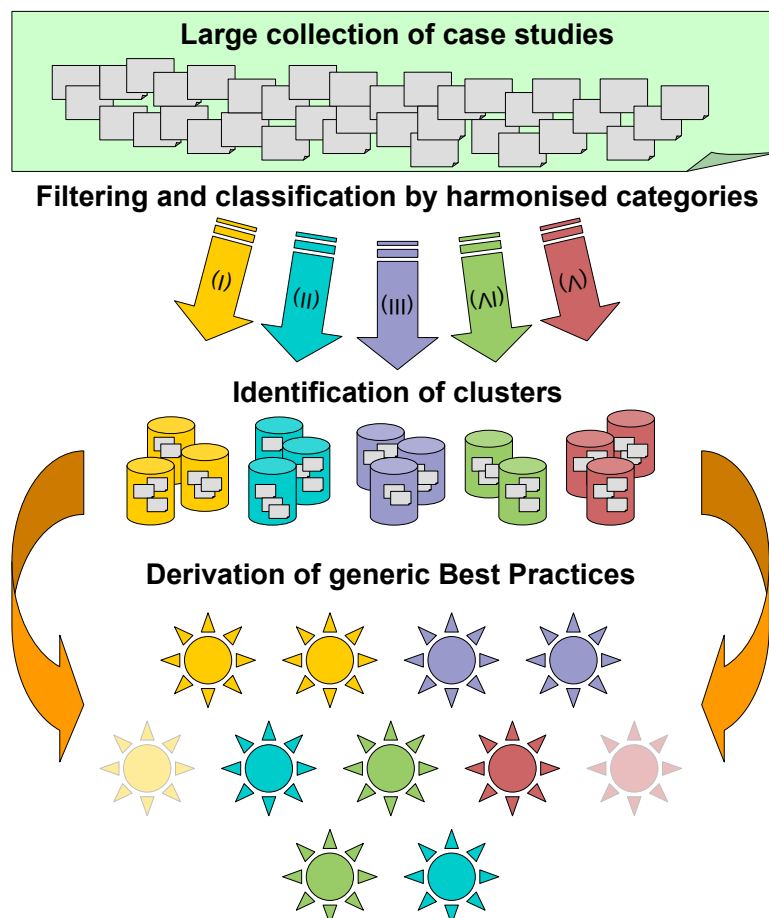


Figure 9: Methodology used to identify and develop best practices

1. Simulation based Energy Design

Scenario

Pentti is currently working on a very ambitious renovation project. His company is involved in the refurbishment of a 125 buildings housing estate, either individual homes or small collective, located on a 24 ha area in the outskirts of Helsinki.

Today he has to evaluate the annual energy needs of the final project and make suggestions to the engineering team which has to decide of the final technical options. Pentti loads the description file of the district in his energy simulation software and instantly visualizes the 3D model created by his colleagues. He enters the current insulation level, materials used, type and position of the openings for each building, and launches a first simulation that gives him a rather precise idea of the current heating and hot water needs of the housing estate. By increasing the insulation thickness of the walls, changing the type of glazing, applying technical corrections to the most impacting cold bridges, he is able to decrease the energy needs by 50%. Testing different ventilation and heating strategies at a building's level allows Pentti to decrease the heating needs down to less than 15 kWh/m²/year.

Concept

BENOSim is based on open standards and on an interoperability approach. The software system has a well-organized, module concept that facilitates adding features and links to other programs. There is no general user interface. The modularity is intended to be the simulation engine around which a third-party interface can be wrapped or specific views and interfaces can be customized. As an example, different simulation interfaces (environments) are available based on type of user (at a district level, energy simulations cover clusters of buildings, while at a building level, the simulations cover the different spaces within a building, and at an individual level, the simulations cover individual preferences, use, and behaviours) allowing for simulation of options and then control at different levels of granularity. BENOSim simulations support decisions through design and operational phases of district and buildings. The system, considers as input not only technical data but also occupancy behaviour and human interaction with buildings. A performance database and energy usage patterns result from the analysis and optimization of real-data. This allows life-cycle support through real-time information.

BENOSim modules are clustered into different simulation environments:

- District level modules: Dynamic district level simulations allow multi-optimization decision support for planning energy efficient districts. For already operational districts, local energy system architecture and control hierarchy is developed and optimized.
- Building level modules: Simulation tools to support Performance Based Design (PBD) for the full design cycle and for new or existing buildings before refurbishment. Target is to assess the technological choices to be made in order to design energy-efficient buildings. Integrated building information models that link directly to building energy simulator can be combined to steer building forms towards maximum energy efficiency in the initial stages of design. BENOSim supports the integration of operational control with building information model, real time measurement data and predictive simulation. A module on occupancy simulations integrates sophisticated buildings energy simulation and detailed human thermal modeling.
- End-user modules: the software system allows the development of interfaces for end-user awareness and control at buildings level. These can as an example be through a control display reporting on usage patterns and their energy consumption characteristics allowing for improvements in energy efficiency.

Provided Service

The Simulation software system supports the design of energy efficient buildings and neighbourhoods (districts), by analyzing different building configurations, different occupation scenarios and the thermal behaviour under dynamic conditions. Receiving energy consumption data at the initial concepts stage allows the client and the design team to influence the design at a stage when changes can still be incorporated. This allows for the client to make economic decisions with regard to building form and building materials relative to annual energy consumption early in the design process. A full complement of sustainable design techniques can simultaneously achieve ultra high energy efficiency and high comfort for occupants using current technologies while reaching energy efficiency at an affordable price. At the operational level, energy use optimization is based on the integration of advanced simulations with optimal monitoring and control based on real lifecycle data.

With modules at different levels BENOSim provides holistic energy efficiency for the built environment, with impact on buildings and neighbourhoods and also on end-user awareness and usage improvement.

Impacts

- District level simulations allow multi-optimization decision support for planning energy efficient districts leading to significant energy savings at a district (neighbourhood level).
- Building level simulations allow for optimal energy consumption, simulation, optimization and configuration of new buildings and refurbished old buildings leading to significant energy savings.
- End-users (building owners) able to visualize energy consumption, and configure and control building energy profiles for improvements in energy efficiency leading to significant energy savings at a local level.

Stakeholders (providers, users)

BENOSim is used by district planners and developers, design and engineering teams, building owners, operators and also by the buildings end-users. Furthermore it can be used by developers and services providers and to support Government regulations. It advocates a paradigm shift from simple design for aesthetics to design for aesthetics and energy efficiency by architects, designers, renovators, etc.

Maturity

Currently, commercial software simulate only isolated parts, e.g. design (space), heating, lighting, ventilation, moisture, etc. Furthermore there is limited interoperability between different tools and simulation levels as for energy management between buildings and district. BENOSim will fill these gaps developing a holistic approach to energy simulation in the build environment.

Current Level of Dissemination

While individual cases exist in different countries, their focus is only on specific disciplines, types of buildings (e.g. new large scale, high-tech importance buildings). There is a need for consolidation of the tools used in the cases to form a holistic energy simulation system that covers all relevant discipline areas throughout the lifecycle of a building.

Future Trends

Future research and development to the software system is expected to:

- Increase interoperability and reliability of the simulation results by validation.
- Increase user interaction and the possibilities to support several different interfaces (n-D visualizations of complexity).
- Include innovative performance indicators and regulations.
- Extend the simulation modules from district to large scale urban planning. Simulation tool to support urban designers to optimize the environmental sustainability of their master planning proposals.
- Development of simulation “dashboards” for districts, buildings, and users. These will through simple interfaces allow for tweaking of sets of relevant variables to compare different alternatives and view the impacts on energy efficiency of each alternative.

2. Early Energy Design

Scenario

Uwe recently acquired a 1500 m² building lot on which he intend to build his own house. He already has some very precise ideas about the final energy consumption he wants to target. But his lot is not ideally exposed and oriented, and in consequence the house has to be carefully designed, taking into account all the constraints (slope, winds, sun exposure, shadings by trees or remote landscape, etc.).

A friend told him about a very convenient software tool that can be used for this purpose: EED-3D (Early Energy Design – 3 Dimensions). This application is designed for non expert users that need to estimate the influence of technical or architectural choices on the energy consumption of a new or renovated building.

This EED-3D tool is indeed very user-friendly: the 3D user interface allows Uwe to very quickly draw a sketch of his future house on a building land with the real characteristics in terms of sun exposure, orientation and so on. Uwe can rotate the house, increase the insulation thickness in the walls or in the roof, change the shape or volume/area ratio, add thermal solar panels and choose between various heating and ventilation equipments and see the influence on the final energy consumption.

There is even an economic analysis module that can plot the energy gains versus the financial investment, and can help the user to choose the best option in terms of return of investment.

Concept

The application described in the above scenario is a simple software tool, with a friendly user-interface where the user can draw the shape of its building. The tool is able to quickly estimate the final energy consumption of a building project, from the very first phases of the design process, using simple rules based on various input parameters, such as insulation thickness, materials used, type of glazing, types of heating and ventilation systems, local climate, orientation of the building, sun availability, local winds, etc.

This kind of tools is to be used by individuals or building owners who need quick inputs about the influence of very early architectural or technical choices on the energy consumption of a building, either for a renovation project or for a future building.

Provided Service

These "early energy design" tools can evaluate the influence of given parameters (depending on the building's characteristics and on the environment) on the final energy consumption of a

building. The underlying algorithms used in such applications are similar to the generic rules that can be found in books and guides (describing bioclimatic architecture principles, for example). Such algorithms have to be determined from physical models, and validated through numerous statistical analyses of experimental data. The advantage of embedding these rules and algorithms in a software application is to give the user interactive, immediate, and quantitative information on the energy impact of each technical or architectural decision. However the accuracy of the obtained results is lower than those obtained from dynamical energy simulation tools.

Such applications can be used either for new building projects, helping the user decide on the orientation, shape, materials of the future building, or for renovation projects, giving valuable information on the thickness of the necessary additional insulation, or on the kind of heating system to be installed as replacement of the old one.

Impacts

Such "early energy design" tools help disseminate "good practices" in terms of building design among individuals or civil engineering students, by giving quick and quantitative information about the influence of architectural and technical choices during the very early phases of a building's design. It is indeed commonly agreed that 80% of the energy performance of a building is determined during the first 20% of this building's design.

By using such tools, individuals can understand the impact of the most influential parameters on the final energy consumption on a building, and then be able to discuss their building's project with architects or craftsmen.

Stakeholders (providers, users)

Users: mostly individuals (since architects and design teams would have more precise, simulation based energy design tools)

Providers: software vendors

National (or European) energy agency: promoting such initiatives (by providing funding or guidelines)

Maturity

The description given in this Best Practice is the combination of several case studies. Current existing tools that provide similar services to those described here are either energy consumption evaluation tools based on rather complex Excel sheets without any 3D user-friendly interface, or simple 3D modelling tools that do not natively include quantitative evaluation of the final energy consumption of the considered building. Some development initiatives aim at linking some of the most widespread energy simulation environments with 3D modelling tools and could thus represent a good starting point for the targeted applications.

Current Level of Dissemination

In Northern and Western Europe, static (as opposed to dynamic) energy simulation tools are currently used mostly by engineering teams and architects, and not much by building owners, but some highly motivated individuals begin to look for such tools that are more user-friendly and do not need expert skills compared to professional applications.

3D modelling tools, used to design various kind of objects (cars, furniture, small devices, as much as buildings) tend to be more and more common because of their user-friendly interfaces.

Future Trends

Future developments (short and middle terms) of such "early energy design" tools include:

- Interoperability with professional modelling (CAD) applications through common standards, so that the very early principles of the considered building could very easily be transferred into professional applications (used by architects, design or engineering teams, builders).
- Economical evaluation module: the calculation of the economical impact of architectural and technical choices on a building's final energy consumption in such tools is not yet included. Prices would be extracted from materials and components libraries, and the user would also be able to add its own custom components or correct some of the available prices. In addition, the economical evaluation module would have the possibility to evaluate different scenarios in terms of energy prices evolution.
- Web-based services: instead of being sold as stand-alone applications, one can imagine that such tools would rely heavily on online materials and components databases that would be updated real-time by the providers themselves.
- Integration of other topics of interest (noise, light, health, security, etc.) for a global optimization of the configuration.

3. Integrated Modelling Solution based on BIM

Scenario

David is an architect who has been challenged to design a new housing complex that is not only aesthetically appealing but is also energy efficient. He realises that now he has to “design for energy”. At first he creates a BIM (building information model) of the housing complex covering its main structural elements, materials and overall geometry. This model is then enriched with lighting, HVAC (heating, ventilation, air-conditioning), and mechanical data models through respective applications that support BIM model import and export. David then imports the enriched BIM into an energy simulation software to simulate and assess the energy profile of the chosen housing complex configuration. He then makes relevant changes for energy optimisation, creates visualisations of lighting and energy use, and sends the updated model to the client for consideration. Once the client approves, the model is forwarded to designers for structural design.

Concept

A Building Information Model (BIM) is used as a collaboration and integration platform between different application domains and disciplines. The BIM is a semantically rich “total description” of a building and associated services. BIM models are stored in model servers and increasingly in distributed model servers and then assimilated/merged to form a whole “total description” and collection of all building elements and services. This supports interoperability across all application domains and disciplines and allows for holistic assessment of a buildings design, structure, and most importantly performance under different assembly and service configurations. By forming the integration basis for data from different disciplines (e.g. structure, material, electric, HVAC, mechanical, etc.) it is possible to assess the energy performance of a building through holistic comparison of different design alternatives. This facilitates informed decision making to allow selection of the optimal design alternative and its configuration for a given purpose by relevant stakeholders.

It should be noted that different domain specific information models exist. Where this is the case, there is a need to have interfaces that map and connect to a commonly shared information model

(BIM). This commonly shared information model (BIM) acts as the basis for integration (model merging) and interoperability (model sharing) between different applications and disciplines.

Provided Service

A Building Information Model (BIM) is a semantically rich representation of a building and associated services. This BIM model is stored in a model server or different layers of the model stored in distributed model servers. These layers typically represent discipline specific (e.g. structure, material, electric, HVAC, mechanical, energy, etc.) views to the model. The model server is where these different layers are merged to form a complete holistic view of the building and associated services. This allows for extracting relevant contextual information from the model to perform various visualization, simulation, analysis, alternative comparison, etc. actions. Where needed, specific applications can be built around the model server to access, modify, and update different building product and service parameters.

The main purpose of model servers is to store, assimilate and make available in real-time all building and associated service information. Architectural models can be merged with structural, mechanical, electrical, HVAC, etc. models to allow for integrated design of buildings and associated services. The impacts of various choices e.g. structural, mechanical, electrical, HVAC, etc. and the implication of these choices on each other in terms of building energy performance can be simulated, visualised and analysed through special applications. This in turn allows for informed decision making in terms of selection of the optimal building configuration for the required energy performance of a building. The chosen building configuration can then be directly sent for production (e.g. pre-fabrication) and on-site assembly. Later real-time building performance can also be monitored, and if needed improved through comparison of different corrective solutions.

Impacts

Key impacts include:

- As design decisions can influence energy performance by up to 80%, holistic integrated design allows for significant energy savings in buildings. This integrated design is made possible through a BIM that is shared through (distributed) model servers
- Holistic access to total building information leading to zero design errors
- Comparison of different design alternatives allows for selection of optimal building configuration
- Through visualization and alternative impact on building energy performance assessment, clients can make informed decisions and select desired building configuration during early design stages
- With BIM model servers serving as the basis for interoperability and collaboration between different applications and disciplines, data coherency is ensured and integrated design possible

Stakeholders (providers, users)

Key current stakeholders include:

- Architects
- Designers (structural, mechanical, HVAC, electrical)
- Contractors
- Facility managers

In the near future, the following additional stakeholders are expected:

- Building owners and operators
- Neighbourhood and increasingly district planners
- Product manufacturers
- Service providers
- Energy providers/distributors

Maturity

The use of product models (e.g. BIM) and supporting model servers has been under significant research and development for more than two decades. While some isolated applications do exist and some early model servers being used, significant challenges still do remain as summarised below:

- Despite significant developments in technologies, interoperability remains a major challenge. With changing discipline specific data models, it is difficult to continue to exchange data in a meaningful way. When there is the possibility to exchange data, this is typically on the basis of the minimal common denominator of shared data. Most if not all applications read-in (import) data and then map this on to the internal data models of the application/discipline and then later export this out. When exporting, data from an application's own data model to a common/shared data model, there is always the risk that application/discipline specific additions are omitted during the export.
- Even when BIM is in use, data sharing is still fundamentally file-based. This leads to redundancy, lack of notification in case of changes to a model, and delayed communication of information. It is also difficult to keep track of the "latest" and "correct" version of a building's information model. There have been developments around model servers, but much more research is needed to fully make use of "distributed" model servers ensuring data coherency, real-time information access, etc.
- There is still a lack of interfaces between different disciplines engaged during a building's lifecycle. Most disciplines continue to have their own data models and only some of these have some form of interface to import/export data from a common shared BIM. BIM model servers and especially distributed model servers still require further research and development.

Current Level of Dissemination

The core concepts of product models in the construction industry have been addressed since the early seventies and standards to support data exchange developed in the eighties. However, the focus then was on file-based data exchange. Furthermore, initial building information models were for architects, while structural designers had their own models.

There do exist today various discipline specific (e.g. structure, material, electric, HVAC, mechanical, energy, etc.) applications that make use of BIM. However, data exchange is still primarily file-based and not truly model server based. Integrated solutions are still very limited and still in infancy stages.

The last five years have seen a significant interest by the construction industry in the potential of integrated solutions built around BIMs stored and shared through model servers. buildSMART™ is an international effort that is gaining momentum and a significant following by industry as it addresses exploiting the full potential of BIM in the construction sector from an industry viewpoint.

Future Trends

- Models will serve as a basis for interoperability between different applications, disciplines, and increasingly collaboration between stakeholders. Interfaces will be used to communicate between discipline specific models and a commonly shared BIM. All information exchange will be through (distributed) model servers to ensure access to real-time information throughout the lifecycle.
- Using model-based design, it will be possible to use tools supporting self-optimization and even optimal configurations of buildings. This is expected to lead to near zero error design, production, site management, and construction.
- Total lifecycle models will contain total building or infrastructure lifecycle information. This will be in the form of integrated design, construction, and as-built models. There will be support for not only model maintenance and updating on demand, but also real-time adaptive models that will adapt themselves for specific functions as needed.
- Solutions for different alternative visualization, analysis, simulation, and comparison. These will for example, support visualization, analysis, simulation, and comparison of different product/service choices and their energy performances during different lifecycle stages.
- Solutions that will ideally support simple “plug-and-play” by users to define and create products/services of choice. Based on these choices, the solutions will optimize (based on a comparison of different product/service alternatives fitting user choice) configure, and even design the product/service.

4. Smart Metering for Energy Consumption Awareness

Scenario

It is the beginning of January and Bill is at home. Since the utility installed a smart meter in his place he has been able to access a web site to check daily and overall consumption, past bills details and more services.

He’s had to make a lot of spending last month and he wants to improve the energy use to save some money. Therefore, he checks the web site and gets to the “energy use” page where he can see some advices such as lowering the heating during the night or turning off lights where there is no people inside.

Advices work pretty fine for Bill because he can see an estimate of how much money he would save by changing his behaviour.

Although Bill’s place is not automated, he is now able to check daily consumption in order to follow the guidelines given by the web site service.

Concept

A Smart Meter provides real-time registration of energy use/generation, offers the possibility to read data locally and remotely, remote throughput control and the ability to read other meters (e.g. gas, water). The following figure shows a scheme of a smart meter.

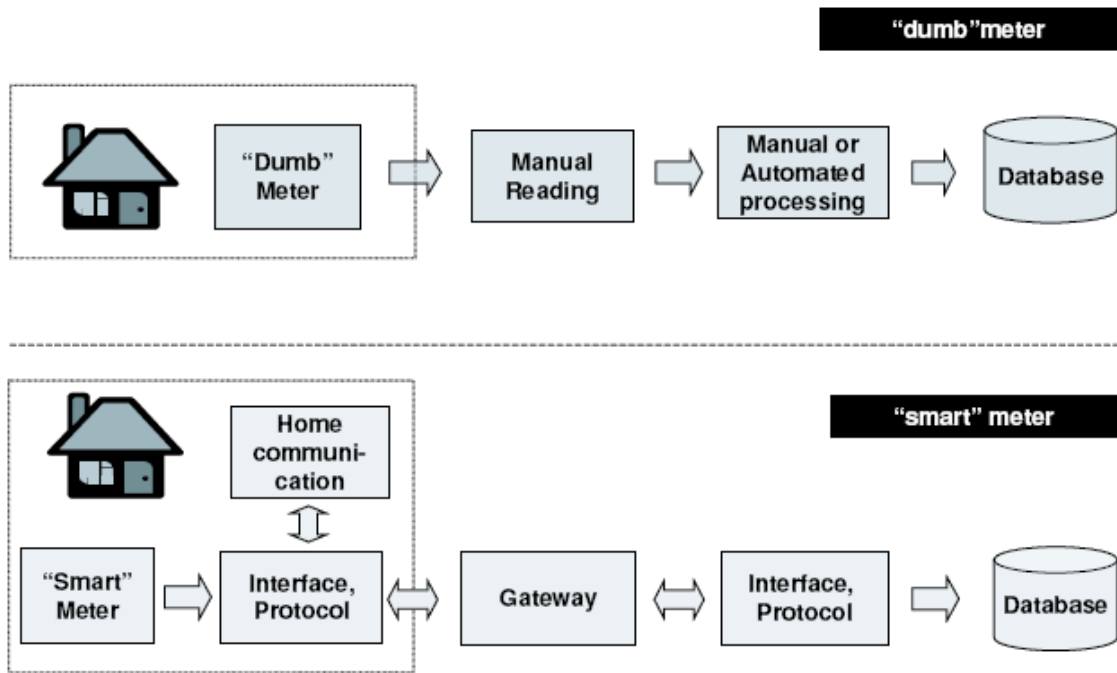


Figure 10: Conventional and smart metering data process

A Smart Meter consists of a solid-state meter, an advanced SSI (Smart Sensor Indicator) module and a communication device. The infrastructure for this communication could be PLC (Power Line Carrier); a wireless modem (GSM or GPRS) or an Internet connection (ADSL). An interface enables connection of the Smart Meter to home appliances and the home display (PC, TV). Appliances can be controlled directly and the display is used to show energy consumption and cost.

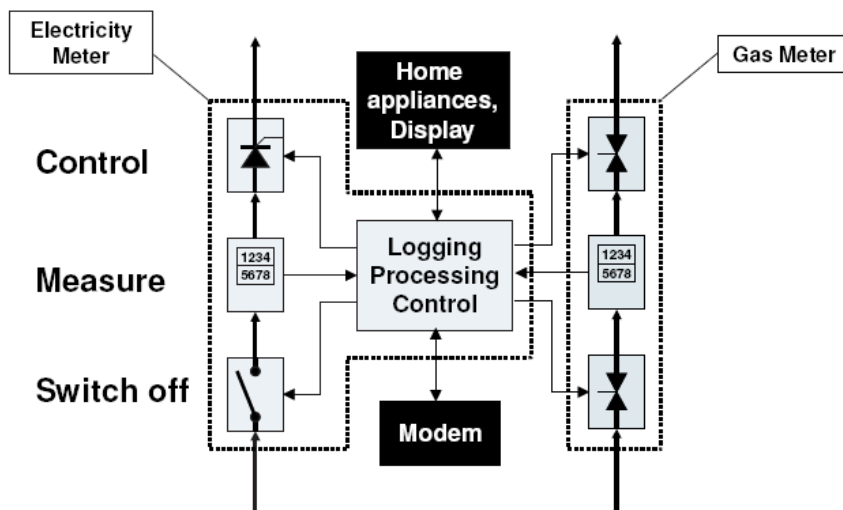


Figure 11: Smart meter configuration

Provided Service

Smart Meters are mainly a part of the infrastructure of an energy awareness system. They provide energy use data to the system so it can be displayed to the end users. Therefore, end users get benefits from smart meters as they have the chance to review on their energy consumption and just by adjusting their behaviour they can reduce their energy cost. Also, the billing process is different as end users can get real consumption data.

Services are made available through the following Smart Meters' capabilities:

- Real-time registration of energy use and generation if possible;
- Possibility to read the meter both locally and remotely;
- Remote limitation of throughput through the meter;
- Inter-connection to local networks and devices;
- Ability to read other meters (e.g. gas, water).

Impacts

From the point of view of energy consumers, the impact of consumption awareness over smart metering means a change in their behaviour. Smart Metering allows consumers to exactly trace households' consumption and they are also able to compare bills with their own data in order to check for mistakes. Hence, it can be stated that the major benefit that comes from consumption awareness is without a doubt a reduction on energy consumption or, in another case, a better use of it.

An experiment called the "Smart meter field test", performed by RWE* in 50 households in Germany demonstrated that informed users tend to apply energy savings measures, thus leading to a decrease in their overall energy consumption.

To the suppliers other major benefit that comes from consumption awareness is the deployment of new and dedicated services to the customers. More innovative and efficient solutions will be released to the market.

Stakeholders (providers, users)

Several parties are involved in the activity such as end users, tech providers, utilities and market operators. However, this overview focuses mainly on consumption awareness which is a service that implements an ICT infrastructure in order to allow end users to monitor their consumption in a more accurate manner. Therefore, there are several stakeholders that can be directly identified by their participation in the value chain of such service: end users, tech providers and ESCOs. Moreover, there are other entities that are not directly involved but are surely affected by the service such as regulation bodies.

Maturity

Smart Metering is a topic that's in the spotlight due to the projects that support this practice. Several projects across Europe, the USA and other countries show that smart metering is technically feasible and promises many benefits.

The consumption awareness over smart metering market is a very active area for technology development. Many solutions on consumer feedback are out in the market but there is no standard for these products. However, they are all compliant with the concept exposed in this study.

A remarkable trend on these technologies is the increasing development of ZigBee enabled displays. Although US and European market are specially linked displays are more established within the US and still being tested in Europe. These artefacts can be offered by both the utility and the manufacturer.

* <http://www.rwe.com/web/cms/de/46308/rwe-magazin/rwe-magazin-archiv/archiv-2008/ausgabe-1/pilotprojekt-stromzaehler-der-zukunft/>

There are other services provided by some utilities. They allow consumers to access a website in order to see their energy consumption, future bills and provide some guidance to save energy.

To summarize, all technologies follow the same concept shown in this survey and provide the same services. Actually, the difference on these technologies relies on design and communication channel.

Current Level of Dissemination

The concept of Smart Metering is widespread and the use of this practice is beginning to have a major importance in some countries. Just to address an example, the US government has recently allocated \$11 million dollars from the budget to the Smart Grid and deploying 40 million Smart Meters over the country. This is without a doubt a major investment that will engage others in the smart metering practice.

Another significant smart meter rollout is the one performed by ERDF in France. The leading electricity operator is willing to modernize the electricity network and improve the performance of its metering system. The test phase will deal with the deployment of 300.000 smart meters in order to prove the system ahead for a national rollout of 35 million smart meters in the years up to 2017.

Future Trends

Smart Metering technologies are available in a digitalized market and constant decreasing prices make those technologies more attractive. Benefits from the different services are quantifiable and already identified. The only issues that stop this market are standards and regulations.

Some governments are already fostering the deployment of these devices and therefore it is foreseen that utilities and end users will be the major players in this market as meters will only be provided by utilities. Other investments from third parties, in order to provide extra services, are being evaluated but the main problem they face is: will they be able to read from the meter? The answer: they will have to establish a previous relation with utilities.

Finally, on technological terms, the imminent rollout of ZigBee enabled displays based on the ZigBee energy profile over the US will lead other network protocols to emulate the ZigBee device range.

5. Building Management Systems

Scenario

Mr. Jones is the facility manager of a complex building of about 10 000 m², with offices, meeting rooms, a company restaurant and 500 daily users. Mr. Jones is a happy man: about one year ago, he convinced his boss that there was a huge potential for energy (and money) savings if a Building Management System (BMS) was installed in the building. And today, the actual figures confirm what he and the supplier of the system presented at that time. Although the cost was not negligible, the return on investment is now confirmed to be less than 3 years.

The BMS is now connected to the heating, ventilation and air-conditioning systems, to many active components in the building (lights, shutters, fans, etc.) and to a lot of various sensors (presence, temperature, humidity, light, etc.). Integration of the system to the existing installation was easy because of the high compatibility with other commercial solutions.

Currently it is winter, and the sun is shining: unoccupied south-facing meeting rooms shutters are left open, in order to maximize solar gains and avoid using the heating system as much as

possible. However, when people enter the meeting room and manually overcome the automatic control, requesting the shutters to be closed (because they need to use a beamer for their meeting), the system adjusts the light to the needed level, starts up heating and adjusts the ventilation rate. When the meeting is over and people leave the room, the presence sensors send the information and the system falls back to the standard setup.

The photovoltaic panels (installed on the building's roof) are also monitored by the central system. The use of the electricity generated by these PV cells is privileged by the BMS (for lighting, other electrical office appliances, etc.) when it is available. It has been sized to cover a good part of net electricity requirements for the whole building.

Maintenance is easier, too: this morning, the system detected an unusual low value for the heat pump's COP (coefficient of performance), probably due to a pressure drop in one of the heat pump's compressors. The system then started the natural gas boiler, bypassing the standard setup that gives the priority to the heat pump when the outside temperature is above 5°C. At the same time, the system switched on an alarm on the central display and sent a mail to the maintenance company, warning that a failure has been detected in the heat pump and that the COP was not at the expected level.

From the central monitoring display (available through the internet, on his laptop at home or on his/her smart phone), Mr. Jones has a full access to the whole system, to all energy consumption balance sheets and can easily adapt the global strategies, considering the system's suggestions based on past and future trends identification.

Mr. Jones is definitely a happy man.

Concept

A BMS (Building Management System) is a computer-based control system that is connected to the building's mechanical and electrical equipments such as heating, cooling, ventilation, lighting, and even insulation and appliances, in addition to power systems, fire systems, and security systems. An advanced BMS also has the ability to control the building's energy production and storage systems (photovoltaic panels, combined heat and power generators, batteries, etc.) along with the possibility to retrieve information from the Internet, like weather forecasts.

It uses a combination of:

- Wired or wireless sensors (for occupancy, movement, light fluxes, internal solar radiations, windows and doors states, blinds, indoor/outdoor conditions such as temperature, humidity, CO₂, air quality, etc.),
- Actuators (for heating, cooling, ventilation systems, blinds, doors and windows, lights, energy production equipments, etc.),
- Meters (for water, air flow, and all kind of energy: heat, electricity, gas, etc.)
- Centralized or distributed/embedded intelligence software, for activity monitoring, timetables implementation, optimization algorithms and user interfaces (real-time data display, alarms, remote control features, etc.),
- A central communication network using proprietary or open-standards protocols (e.g. DALI for lighting, TCP/IP, BACNet, Lonworks, KNX or Zigbee...)

Provided Service

The main goal of current BMS is to control all energy components of the system in an optimized way to minimize global primary energy consumption while ensuring optimal indoor comfort

(according to user needs and wishes) and safe operation of all controlled equipments, based on three main functions:

- Advanced monitoring (including maintenance supervision, failure detection, diagnostics)
- Optimized control
- Real-time and consolidated reporting (including benchmarking features)

Through the use of optimization algorithms (based on neural networks, fuzzy logic or genetic algorithms), a BMS computes all collected information (from sensors, meters, actuators, micro-chips and embedded systems) and provides an efficient and optimized control of all active equipments in a building. To manage energy use, it can monitor various parameters in the building such as temperature, humidity, energy usage and occupancy patterns. By doing so, services such as air conditioning, ventilation and heating, lift services, hot water systems and lighting are able to be controlled in ways that minimise energy use while optimising comfort and functionality. Most advanced systems can mix activity information (level of human activity, in order to set the internal conditions according to the level of activity of the users), weather forecasts (link to the Internet), indoor and outdoor conditions (temperature, humidity, air quality, etc.) and information coming from all connected devices (status, alarms, consumption ...). The optimization is based on schedules (time of day, day of week, holiday periods), presence information, external weather conditions, user wishes collected through human-machine interfaces, and on the building's behavior. A lot of the needed information is provided during the installation and first set-up phase of the system, but a BMS is of course reconfigurable according to the potential changes in the building's configuration and usage.

A BMS also features reporting capabilities, and can inform the users, energy managers or building owners about the status of the building in real-time, in terms of energy global or detailed consumption, status of all connected devices, equipments and systems.

A BMS is a very important tool in tuning the operation of current buildings (especially the large and complex ones), and becomes essential in the operation of high-performance or positive-energy buildings, because of the need to precisely balance the behaviour of all components (energy production, consumption or storage) in the building.

By controlling the energy production and storage systems in addition to the "standard" HVAC equipments in a building, a BMS is a key element for the building to be connected to a "smart grid", an intelligent energy network that takes advantage of interactions between the energy providers and end-users, where consumers become "prosumers" (producers-consumers).

Impacts

By controlling up to 70% of the energy use in a building, BMS using efficient algorithms can lead to improved comfort in buildings while reducing energy consumption. This ensures that operating costs are minimised and occupants are more comfortable.

Since every building is different and all kind of configuration can exist, it is difficult to precisely predict how much energy savings can be achieved through the integration of a BMS in a building. It is generally admitted that the energy savings can range from 10% to 40% compared to the same building without a BMS, while maintenance costs are reduced by 10% to 30%.

Stakeholders (providers, users)

In the BMS market, current stakeholders are:

- Building tenants/users/occupants
- Building owners, renters

- Building managers (operations/facilities managers)
- Maintenance companies
- Energy providers/distributors

In the near future, new stakeholders could appear:

- Architects / design teams
- Planners

Current providers of BMS are either big companies or SMEs.

Maturity

A quick market survey shows that lots of commercial offers exist, but no standard applies to BMS solutions. Every building is a one-of-a-kind and a BMS has to be finely tuned to the precise building it is installed into.

In term of commercial offer, two levels have been identified: most of the time smaller companies tend to provide smaller scale solutions (for individual or small collective residential buildings), while big, international companies are selling solutions that apply to large and complex industrial, commercial or office buildings or even groups of buildings.

The concept of BMS applies to a lot of different applications, from the simple integrated and intelligent HVAC operation system or smart lighting system, to the full-featured optimized application described in the previous sections, connecting all energy devices in a building, from lights to HVAC, along with lifts, security and energy storage and production equipments.

Most of current systems only provide part of the described services, and the trend is to evolve towards fully integrated systems, connecting more and more active elements in a building.

Current Level of Dissemination

While the concept of Building Management Systems is quite widespread, the usage is not, especially in smaller buildings. In addition, it is worth mentioning that, for large installations, the most current situation is still to have independent sub-systems (controlling HVAC, lighting, etc.) that do not follow a holistic and systemic approach.

However, Building Management Systems tend to be more and more common in recent complex industrial, commercial or office buildings, which consume huge amounts of energy and where efficiently operating all energy devices in a building becomes too complex to be done manually or with traditional methods and recipes.

Moreover, a BMS adds value to the building it operates (because of better energy use, ease of operation and maintenance). In consequence, the use of BMS is spreading faster in private-owned buildings than in public ones.

Future Trends

Future developments (short, middle and long terms) of BMS include:

- More integrated systems, taking into account more and more components and equipments in a building (this aspect requires a higher level of interoperability between sub-systems);
- Closer interaction with the energy network – capacity to control energy use in the building depending on future energy costs, anticipate higher costs and store energy (heat, electricity) using batteries or thermal mass;

- Energy benchmarking features: compare the building with similar buildings (introducing ranking possibilities), history of energy consumptions;
- Disaggregate end-use consumptions (get detailed views separated for HVAC, lighting, by floor, by room, etc.);
- Integrate widespread energy communication standards for energy devices (consumption, production and storage) and controllers (sensors, actuators) interconnection;
- Use prediction to reduce the number of sensors connected to the control network: i.e. extrapolate data obtained for a room equipped with sensors for similar rooms;
- Link BMS with design phase (e.g. link with BIM)
- Connection with external services and interfaces with stakeholders (e.g. billing system interfaced with BMS in case of a hospital).

6. Wireless sensor networks for energy performance monitoring

Scenario

Mr. Baulger is the Facility Manager of a newly constructed research institute. The building is powered from renewable micro-generation facilities for the generation of electricity and hot water supported by a gas boiler. A sophisticated Building Management System (BMS) and Heating, Ventilation & Air Conditioning (HVAC) systems are installed and managed separately by an external company. The building is split into several zones with different specific requirements for working environment conditions (i.e. industrial fridges area, chemical laboratories, meeting rooms, open-plan offices etc.), so a zone-based metering of energy consumption and sensing of comfort levels is required.

The intensive difference in weather scenarios during the year, as well as many different occupants' preferences and their behaviour makes it difficult to manage the HVAC settings and maintain acceptable comfort levels, reducing energy consumption and subsequently the cost for building's maintenance and operation.

Therefore, the Facility Manager needs to examine and store these parameters for the building all around the year. He also needs to organize sub-metering in zones of the building, and address the "ownership of energy data" issue, i.e. to avoid the need to approach BMS providers for getting an access to that data.

All of these factors motivate Mr. Baulger to contact an engineering company and to plan specific actions for improvement of energy performance monitoring within the building.

From their perspective, the improvement in management of the building should be done through the application of WSN for optimised energy data collection, aggregation and analysis for the generation of reports and actionable information (starting a chain of actions and reactions of people and equipment) for decision support. This will help to perform on-time and predictive adjustment of set-points for building climate-control equipment to achieve maximum comfort for the occupants and stable internal environmental conditions.

WSN will not require additional wiring (save installation cost), will not harm the interior and design of the facility (e.g. with application of non-intrusive wireless meters for gas, water etc.), but will provide the flexibility of re-installation in case of circumstances' change. Separate zone-based sub-metering will allow more effective energy cost distribution.

Concept

There are a number of different topologies for WSN existing at present.

A brief discussion of the network topologies that apply to wireless sensor networks are outlined in the following part.

- A Star Network – such a topology, where a single base-station can send and/or receive a message to a number of remote nodes. The remote nodes can only send or receive a message from the single base-station; they are not permitted to send messages to each other.

The advantages of this WSN topology type - simplicity of topology, ability to keep the remote nodes at minimum power, low latency communications between the remote node and the base-station.

The disadvantages of such a network topology type - limited range of base radio transmission with all individual nodes; while only single node is managing the network, it is not as robust as other networks topology types.

- A Mesh Network - allows for any node in the network to transmit to any other node in the network that is within its radio transmission range.

The advantages of this WSN topology type - redundancy and scalability of the network; the range of the network can be easily extended by adding more nodes to the system.

The disadvantages of such a WSN topology type are: the power consumption of the multi-communicational nodes is usually higher (in some cases means smaller batteries lifetime); there is a proportional dependency between the number of nodes and the time to deliver the message.

- Hybrid Star – Mesh Network - a hybrid between the star and mesh network, where the lowest power sensor nodes are not forwarding messages, but some other nodes on the network are enabled with the capability to forward messages from the low power nodes to other nodes on the network. This WSN topology is known as ZigBee.

This balanced solution for WSN topology came from the first two; there is an advantage of such a topology to have a tenable communication structure of the network with reasonable power consumption and speed of messages' transferring.

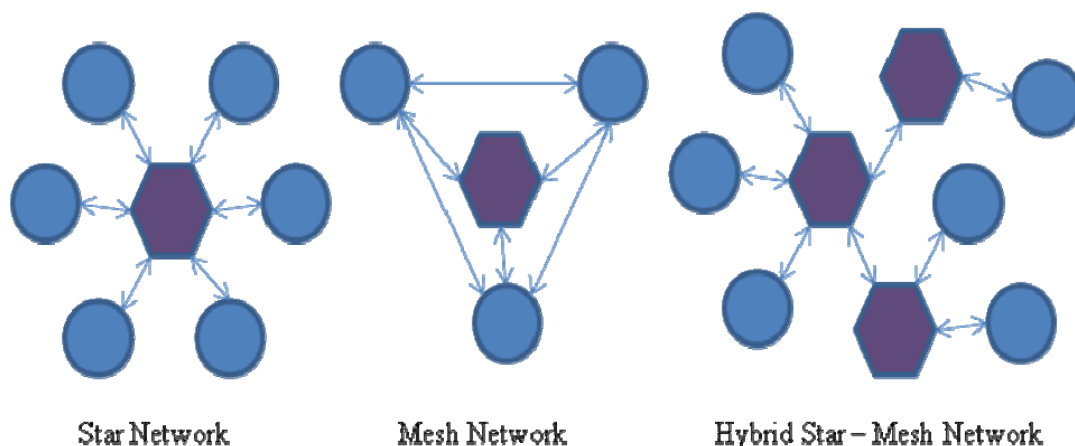


Figure 12: Types of wireless sensor network (WSN) topologies

The wireless sensor network architecture is based on a recently released IETF 6LoWPAN (RFC 4944) open standard for IP communication over low-power radio links – IEEE 802.15.4 represents one such possible link. WSN LoWPAN networks are connected to other IP networks through one or more border routers forwarding packets between different media including

Ethernet, Wi-Fi or GPRS, and storing WSN data to a bulk data management system, such as a data warehouse.

Provided Service

In most cases the Wireless Sensor Networks are designed for monitoring and surveillance tasks. A typical situation is the use of WSNs for detection and monitoring of different environmental scenarios. The system installed aims to validate the proposed architecture by demonstrating that accurate measurements of air-temperature, air-humidity, illumination, and energy consumption for particular rooms in the target building can be achieved.

The application of Wireless sensors' communication will:

- Eliminate the need for expensive, time-consuming, and nonflexible infrastructure deployments;
- Permit flexible and more easily scalable sensor network configurations;
- Provide the framework for new efficient applications.

Impacts

From the point of view of energy managers the impact of WSN on facility monitoring means an improvement of equipment (e.g. BMS) operation, since data is dynamically acquired from the environment as opposed to being manually entered by an operator. Furthermore, the flexibility of wireless networks (while data is distributed across nodes, and geographically dispersed nodes are connected by undependable links) gives more challenging opportunities for measurements, particularly for non-intrusive meters, re-arrangements of network/facility, savings installation costs and facility protection. These applications provide low-latency, real-time, and high-reliability supportive and actionable information for building monitoring and management.

Stakeholders (providers, users)

Current stakeholders are:

- Building owners, decision makers;
- Facility managers;
- Maintenance companies;
- Consulting companies (in the field of energy efficiency);
- Designers of BMS and other measuring systems and components.

Maturity

The main idea of sensor networks was initially introduced approximately two decades ago, when benefits of sensor networks were recognized, but the first applications were mostly limited to the military services. Technological achievements in the past decade have completely changed the situation. Micro-Electro-Mechanical Systems (MEMS) technology, more reliable wireless communication, and low-cost manufacturing have resulted in small, inexpensive, and powerful sensors with embedded processing and wireless networking capability. The WSN, with their constant evolution, need more and more practical and effective WSN Management Tools (WMT) for large-scale deployment, taking into account the resource constraints of wireless sensor nodes (e.g. LiveNCM^{*}).

* <http://www.bfrl.nist.gov/oa/publications/gcrs/04867.pdf>

Current Level of Dissemination

At the present many different companies around the world are dealing with development of WSNs and their components. One of them, ZigBee™ Alliance, is an association of companies working together to enable reliable, cost-effective, low-power, wirelessly networked monitoring and control products based on an open global standard. Recently, ZigBee announced its intention to expand its participation in the European Union's various standardization efforts. The Alliance will focus on the European Union's Smart Grid programs and on meeting the needs of the EU implementation of ZigBee Smart Energy in the Home Area Network.

Future Trends

Wireless sensor networks can be used in many new applications, ranging from environmental monitoring to industrial sensing. The IP V.6 delivers more security especially if it comes to the integration of monitoring and actuation networks.

Networks of small, possibly microscopic sensors embedded in buildings and machinery/equipment, performing automated continual and discrete monitoring could radically enhance our understanding of our environment and improve our management abilities.

Wireless sensor networks promise to revolutionize the way we manage our environment by enhancing our senses.

7. Standards based Energy Performance Assessment Software

Scenario

Samuel is working in a middle-sized engineering company of the buildings sector, which is involved in the thermal evaluation of new buildings projects and renovation operations. In his team, he is in charge of checking the compliance of each project with the national standards for energy performance of buildings. For this, he uses a newly acquired very convenient and user friendly software tool, called "EPBTool" (standing for Energy Performance of Buildings Tool), which is based on the calculation algorithms provided by the National Technical Center for Buildings. The NTCB is in charge of writing the core calculation code, relying on the rules defined in the national standards, and making it available to software companies, who create user interfaces and sell fully packaged commercial applications. Unlike similar energy performance evaluation tools Samuel used in the past, EPBTool can even read files from widespread CAD applications, speeding up the process of describing the building and its systems, which is usually done manually through the (sometimes unfriendly) user interface. Since the standards for energy performance of buildings integrated more and more features, this step became more and more painful, and the risk of mistake increased significantly. Now, with EPBTool, based on NTCB's calculation core, checking the compliance of a building with the latest energy standards is both very easy and secure. The tool itself knows all the rules and can immediately tell Samuel where things are wrong. Changing a technical parameter (insulation thickness of a wall, type of boiler) is very easy and the changes are automatically reflected in the final energy consumption results given by the tool. The tool even knows the consumption levels and minimum requirements that are needed to obtain a specific label (HEP – High Energy Performance or VHEP – Very High Energy Performance, which are respectively 15 and 30% below the conventional limit).

Concept

Standards for energy consumption in buildings (either based on national or European regulations) have been translated into calculation algorithms by a non commercial public organization, which is involved in the definition of the standards themselves. These algorithms are freely available as open-source code. Following the open-source and public licenses principles, it is allowed to reuse open-source code in commercial (closed-source) applications. The core algorithms, which can be coded in C#, C++, Java or any other language that is easily maintained and that can be used to generate interoperable components, are freely reusable in commercial applications. The energy consumption results returned by the applications have to be checked and validated by the public organization who still keeps the responsibility of the core algorithms. At the end of the process, certified "energy consumption assessment" applications are available on the market and every building project (either new or renovation) has to be validated through the use of such a certified tool, and the final energy calculations have to be available.

Provided Service

National laws stipulate that every new or renovated building's energy performance has to be checked using a certified commercial application based on the calculation algorithms. This step occurs during the design phase of new buildings projects or refurbishment operations and is usually performed by architects or engineering teams. The considered applications usually feature user-friendly user interfaces that make it easy to describe even a complex building, in terms of envelope (materials, insulation level, geometry, etc.) and installed systems (not in details, but using simple and generic rules and performance rates). The results of the calculation by certified tools have to be checked by an audit company, which verifies that the calculation tool has been correctly used and that the results comply with the current regulation of the country.

Impacts

Requiring (by law) for every new or renovated building the assessment of its future energy consumption using standards-based certified and user-friendly software tools is a way to ensure the widest and fastest diffusion and adoption of the standards.

In France, one of the first European countries that chose to support the national energy standards by freely available open-source calculation algorithms, the application of the RT2000, RT2005 and soon RT2012 (Réglementation Thermique, meaning "Thermal Regulation") drove the buildings sector from 150-200 kWh/m²/y in average to 50 kWh/m²/y for new buildings in 10 years (from 2000 to 2010).

Stakeholders (providers, users)

Provider of the core algorithms: The provider of the core algorithms shall be a public organism or non commercial organization, involved in the definition of the national standards. Since at the end the code is open-source and has to be freely distributed, this entity has to be paid by public funds.

Commercial software vendors: These are private companies that reuse the calculation algorithms and include them in fully packaged commercial applications.

Users: The users are professionals only: engineering teams, architects. Using the commercial applications provided by the software vendors, they have to check that the energy consumption of the building complies with the standards.

Maturity

In France, the 3rd generation of calculation algorithms based on national energy performance of buildings regulation is about to be published. The process of releasing the calculation core about the same time as the standard is adopted is now fully operational. The importance of the calculation core in the standard is currently such that, instead of relying mainly on texts and laws for describing the calculations that have to be performed, the core module itself is now considered as the reference and the law now simply gives the general trends and specifies when and how the up-to-date core has to be used for buildings projects (either new buildings or refurbishment operations).

Several software vendors have entered the market and closely follow the evolutions of the standard and the algorithms, as soon as new versions are released.

Current Level of Dissemination

From the collection of best practices and information from experts, it appears that so far only France chose to implement the energy performance in buildings standards into a freely distributable calculation core to be embedded into commercial applications. The concept itself of supporting the application of national standards for energy performance in buildings by a freely available open-source calculation module does not seem to be widespread. In a practical way, since the application of the European EPBD (Energy Performance of Buildings Directive) is under the responsibility of each member state, the apparition of a global offer at the European level is not possible.

However, the concept itself can be developed in other countries. It would be possible in each member state to have one or several software vendors packaging the core module into full-scale applications, using graphical interfaces to enter the necessary data.

Future Trends

Future developments of this "Standards based energy performance assessment software" concept include:

- Link the core module with BIM (Building Information Model) applications by using a common standard for the description of the energy-related characteristics of a building (geometry, used materials, HVAC systems, etc.)
- The implementation of dynamic simulation capabilities to better estimate summer comfort in the considered building
- The support of new, innovative HVAC systems (compact systems, improved ventilation, etc.) so that the calculations about energy consumption are more precise and better taken into account

8. Energy Performance Audit Solutions

Scenario

Mr. Brown is the facility manager of a public library built 30 years ago. With the increasing pressure put by the authorities to renovate existing public buildings in order to contribute to the reduction of primary energy consumption and GHG emissions of buildings, Mr. Brown is bound to take appropriate measures to start renovating its library by the next 2 years.

The local regulation makes compulsory for him to realize an energy audit of its building prior to the renovation. This process includes two main steps. The first one has already been achieved. It

consisted in realizing a simplified energy performance diagnosis that allowed rating the overall energy efficiency of the library, and identifying and assessing the sources of energy savings. At that time an energy performance certificate, following the national implementation of the European Performance of Building Directive (EPBD), was delivered and displayed at the entrance of the building. Mr. Brown is now considering the second step of the process which consists in a complementary and more detailed energy audit of the library.

This detailed energy audit should address the thermal behaviour of the building envelope, the quality of the energy equipments (HVAC, lighting, domestic hot water) how they are controlled, as well as the consumption of other electrical appliances (lifts, office automation, etc.).

To that end, Mr. Brown decides to approach an engineering and consultancy company that offers energy audit services using a pool of sensors disseminated at various places inside the building to get more accurate and actual information on the building operational conditions (energy consumptions and usage). This information will allow him to make more informed decisions on the appropriate scheme of measures to be taken to renovate the library during the coming years. He will feel more comfortable with his decisions since the impact of the renovation measures and the ROI will be better ascertained.

Concept

Preliminary audits may be performed to identify the main tracks of improvements and decide upon complementary investigations for improving the performance audit. Full audit solutions finally provide recommendations allowing the planning of energy saving measures at short, medium and long term.

Complementary to the collection of utility data, the number and placement of sensors and smart meters depend on the type of information that is expected to be collected, as well as the accuracy and detail level of the energy performance audit.

The measurement period is usually a few weeks (typically 1 to 4). Collected data can be extrapolated to the whole year by using seasonality charts. Sensors and smart meters may include e.g.:

- Multi-channel electrical energy consumption data logger
- Flow meters (gas...)
- Temperature, humidity sensors
- Thermal fluxmeters
- Presence sensors
- Pluggable energy meters for electrical devices
- “On” and “Off” time lighting sensors

The sensor installation should be made as easy as possible since it is fundamentally a mobile solution. As a consequence, Power Line Communications (PLC) or Wireless Sensor Networks (WSN) is favoured to allow fast, accurate and non invasive measurements.

Provided Service

Energy audit solutions that include data metering (w.r.t functioning, consumption, envelope behaviour, etc.) provide more accurate and actual information on energy consumptions by differentiating the different usages (heating, air conditioning, ventilation, tap water, office automation, etc.) and also the different locations inside the building. They allow a more accurate diagnosis of the building energy performance (compared to standard energy performance diagnosis that follow the implementation of the Energy Performance of Buildings Directive –

EPBD, and are most often based on energy bills for tertiary buildings like office buildings), and provide buildings owners or facility managers with information likely to guide them in the choice of renovation measures.

Besides, audit solutions can also lead to the proposal of recommendations for a whole renovation plan over the coming years, at short, medium and long term. By benchmarking a stock of existing buildings, energy audits can support the comparison between different buildings (of the same owner), as well as the exchange of information and experience and good practices in energy conservation.

Impacts

Energy audits allow not only to guide towards the best renovation measures, but also to better appraise the energy savings. It then avoids making inappropriate decisions for refurbishment of buildings, or false estimates of ROI. For buildings owners, it helps putting money on the best possible investments.

Stakeholders (providers, users)

Current stakeholders are:

- Building owners, decision makers
- Facility managers
- Maintenance companies
- Consulting companies (in the field of energy efficiency)
- Designers of data logging and measuring systems

Maturity

Several engineering and consulting companies already offer energy performance audits. Infrared thermography is often part of detailed energy audits. But the use of sub-metering to supplement utility data with more actual and detailed information on energy usage and consumption is more recent and under development.

Current Level of Dissemination

Energy audit activities are progressing since national regulations, in many European countries, are imposing measures to renovate the existing stock of buildings, especially public ones, in order to reduce their primary energy consumption and emission of greenhouse gases. They go beyond the simple delivery of energy performance certificates (as an application of the Energy Performance of Buildings Directive) by better informing building owners and facility managers about the actual energy efficiency of their buildings.

Future Trends

Future developments include:

- Development of analysis tools to predict the energy savings (associated to renovation measures) with better accuracy and reliability, and support the decision-making process – Link of actual building operational data with Building Information Models (BIM) and Facility Management tools
- Taking into account the influence of occupant's behaviour on the overall energy performance
- Harmonization of calculation methods (to allow easier comparison and benchmarking)

9. Websites for collecting and disseminating energy-efficiency "good practices"

Scenario

Mr. Dupont is leading the design team in a large construction company established near Paris (France). He has been recently given the responsibility of designing a low-energy office building in the South of France. Mr. Dupont has previously worked on more traditional projects, and is not fully aware of all technical solutions that can be deployed to achieve such kind of energy-efficient buildings. Moreover, he never participated to the design of buildings in this area of France, and doesn't know the local market specificities and building techniques. The local representative of the company could give him some help, but he prefers to get a deeper knowledge on the available solutions before.

Mr. Dupont knows that a new web portal has just been opened that gives access to a reference database on national low-energy consuming building projects, as well as a lot of information on energy-efficient buildings, energy saving measures, statistical data (e.g. on the most used techniques in each region), current regulations, and software tools for energy design or performance assessment of buildings.

By filtering this large database with the specific constraints of his project, Mr. Dupont accesses to a range of exemplary buildings similar to his project and erected in the same region. This provides him with very valuable information to make technical choices and draw the main lines of the building (at the level of its envelope and equipments). He is also able to get reference data on the energy savings and better appraise the Total Cost of Ownership (TCO) of the expected investment.

Concept

Dissemination of relevant information and diffusion of best practices are key factors to develop awareness of construction stakeholders in energy-efficient buildings and sustain a widespread development of such kind of buildings. Web information portals represent an efficient means to achieve such large dissemination. The main objective is to raise awareness through the collection of information from exemplary projects and their presentation in a way to allow benchmarking by all concerned actors.

Provided Service

Content of such web sites may include e.g.:

- Databases on energy-efficient building projects, including information on the geographical location, the building type, the constructive system, the characteristics of the equipments and energy management system, etc. It is expected that more detailed information may be obtained only on request to the building owner or other project actors. The scope can be both new and existing buildings, residential or tertiary buildings.
- The regulations, certifications and labels prevailing at European, national or local level.
- Information on methods and software tools for energy design, energy performance assessment or energy auditing.

This content can be completed with news, events, FAQs or Blogs. Such kind of web portal is collaborative by nature. Information can be uploaded by buildings owners or constructors, but to be fully trustworthy it has to be validated (in terms of results or at least in terms of applied methodology) by some officially agreed body like a national or local energy agency.

Impacts

Expected impacts are:

- Enhanced awareness in energy-savings measures and techniques
- Sharing of experience and knowledge
- More cost effective investments in efficient and proved solutions, with higher ROI
- Future regulations based on more documented material (through statistical analysis)
- Development of local markets in energy-efficient technologies
- More focused actions for training, and aid to economic development and innovation
- Multiplier effect of good practices

Stakeholders (providers, users)

Current stakeholders are:

- Building owners, decision makers
- Designers
- Builders, construction companies
- Consulting companies (in the field of energy efficiency)
- Funding bodies, national and local public bodies

Maturity

Information web portals are common ICT instruments to disseminate and share knowledge on many topics, including energy-efficient buildings. The most challenging research issues today remain the collection of benchmark data and the development of appropriate semantic indexing of the web site content that support the development of advanced search capabilities allowing end-users to retrieve relevant information according to their profile and project context.

Current Level of Dissemination

Web sites providing information on the energy regulatory framework applying to buildings are already common at European or national levels. But those web sites providing databases of reference energy-efficient buildings are just arriving since exemplary low-energy building projects are multiplying. The challenge is to get an equal technical and economical level of description for each project that allows easy comparisons between projects.

Future Trends

Future developments include:

- Semantic content structuring using reliable key performance indicators w.r.t. energy-efficient buildings
- Knowledge collaborative services supporting the setting-up and development of user communities
- Coupling decision-support tools with reference energy-efficient buildings databases to provide help to design for new buildings, or help to retrofit for existing buildings

10. Smart Grids

Scenario

Mr. Murray is the owner of a house in a small neighbourhood far from the city. His house’s energy demand is controlled by a BMS (Building Management System) that is hooked to the Smart Grid. Therefore, he is able to manage loads from the grid and local generation.

Today, local energy generation is low and the BMS forecasts an extra load from the Grid will be necessary. For that purpose Mr. Murray sets permissions to negotiate with the Local Energy Market Operator.

The Market Operator has already forecasted power system conditions for the next 24 hours, based on energy schedules and prices already submitted, ancillary services available, weather conditions, day of the week, scheduled outage information from transmission and distribution operations, and real-time information from transmission and distribution operations, etc.

Mr. Murray is now able to retrieve real-time prices from the operator and fix a deal to get the precise energy loads. Moreover, the BMS uploads its scheduled information in that same moment to the Grid and the current situation is re calculated by the Market Operator so it can deliver accurate information to other clients.

Concept

A new paradigm about how buildings interact with the energy grid is starting to be taken into account by the different stakeholders participating in the energy management and trading market. Smart Grid is the transformation of the energy supply chain (i.e. from energy generation, transmission/distribution... to customers) that takes advantage of the available technology for the next generation of electricity grid. Certain attributes of Smart Grids are currently available in use by some countries around the world, which are recommended to be best practice.

The table below illustrates some examples of core functionalities offered between ‘Traditional Electricity Grid’ and ‘Next generation Smart Grid’.

Table 1: Functionalities of Grids

Traditional Electricity Grid	Next Generation Smart Grid
<ul style="list-style-type: none"> • Central-based model for energy generation from often large, distant power stations 	<ul style="list-style-type: none"> • Distributed-based model for energy generation from variable sources e.g. micro-generation, solar photovoltaics, etc)
<ul style="list-style-type: none"> • One-way power flow capability via distribution lines to consumers 	<ul style="list-style-type: none"> • Two-way power flow capabilities between the building and the energy grid
<ul style="list-style-type: none"> • Limited connectivity at the distribution level for grid automation and monitoring 	<ul style="list-style-type: none"> • Greater connectivity to the in-home network and personal computers
<ul style="list-style-type: none"> • Limited consumer participation 	<ul style="list-style-type: none"> • Consumer driven market to make ‘buy and sell’ energy decisions to achieve cost savings and energy efficient building

A Smart Grid is an advanced electricity grid that employs a control network that integrates with many other sub-networks (or microgrids), consisting of communications and ICT systems. That is, many sub-systems with various ownership and management boundaries are interconnected to provide end-to-end services between stakeholders and among intelligent electronic devices. A

Smart Grid should also possess the capabilities to integrate with renewable energy sources, distributed generation and storage, etc.

Within each network of micro-grids, the possible technologies to support end-to-end processes consisting of network and ICT technologies, including Home Automation Networks, Smart Meters, Concentrators, Advanced Metering Infrastructure, Wireless Access Networks, Local Area Networks, and Wide Area Networks. Based on Smart Grid functional requirements the control network should provide the capability to enable an application in a particular domain to communicate with an application in any other domain over the information network, with proper management control as to who and where applications can be inter-connected. Within each network of integrated micro-grids, security issues including confidentiality, integrity and availability, are required to ensure the Smart Grid information and related information systems are properly protected.

The physical and/or logical links within and between these networks, and the links to network end points, could utilize any appropriate communication technology that are currently available or yet to be developed and standardized in the future.

Smart Grid needs to be overlay on the energy supply chain for optimisation, including Energy Generation, Transmission/Distribution, Retail Operations, Metering, and Customers. Examples of smart grid applications that could potentially be deployed in the various domains are:

- **Energy Generation** – integration of traditional resources, micro-generation and storage.
- **Transmission/Distribution** – Utility Asset Management, Two-way Power flows, and Active Distribution Networks
- **Retail Operations** – Web and business information processing
- **Metering** – Advanced Metering Infrastructure, Smart Meters, and Demand side response management
- **Customers** – Flexible tariffs, make ‘buy-and-sell’ decisions.

For customers, we could introduce flexible tariffs in addition to the existing peak or off-peak tariffs that the utilities may offer to the end users. The idea of the flexible tariff option is to offer a tailored price that varies according to changes in energy levels in different time-periods of a day/year. That is, for some days the energy that the utility sells has a more expensive price than others.

The type of the day is dynamically determined by the national electricity grid at the end of each day for the next day, and transmitted by the Utility (electricity Distributor) to all the smart metering devices. This kind of tariff is an incentive to lower energy bills and also to manage extreme peak demand period.

Provided Service

The main advantage of the real-time interaction between the building and the energy provider has two faces. The first one is that the end user obtains a better price for the energy that is consumed in the building. The other one is that the utility can take advantage of the smart grid (flexible tariff, real time consumption information) possibilities and adapt in a more efficient way the resources at one time. The combination of both aspects enable in the end the energy efficiency in the grid, and hence, in the building as they are an active element in it.

Impacts

Although the Smart Grid is not yet fully implemented, several long-term benefits can be identified:

- Significant reductions in residential peak demand energy consumption achieved by providing real-time price
- Additional reductions in residential peak demand by fully integrating the utility system with distributed generation technologies
- Up to 30% reduction in distribution losses from optimal power factor performance and system balancing
- Potential carbon footprint reduction as a result of lowered residential peak demand and energy consumption and improved distribution losses
- Possible reductions in the number of customer minutes out as a result of improved abilities to predict and/or prevent potential outages, and more effective responses to outages and restoration
- Expected deferral of capital spends for distribution and transmission projects based on improved load estimates and reduction in peak load from enhanced demand management
- Potential utility cost savings from remote and automated disconnects and reconnects, elimination of unneeded field trips and reduced customer outage and high-bill calls through home automation

Stakeholders (providers, users)

Specific stakeholder groups that are identified in the value chain of the Smart Grid.

Users:

- Consumers: This group comprises the end users of electricity. They may also generate, store and manage the use of energy at a local level. Three customers are identified: commercial/building, home and industrial users.
- Professionals: Network and Energy Market operators.

Utilities:

- Engages in the generation, transmission, and distribution of electricity for sale generally in a regulated market.

Service Providers:

- ESCOs, the ones that provide services to electrical customers and utilities.

Maturity

Moving forward towards the Smart Grid can't be done without adopting a systems view. Utilities and Policymakers alike in search of a starting place need look no further than the Smart Grid Maturity Model (SGMM). The Maturity Model creates a roadmap of activities, investments, and best practices with the Smart Grid as its vision. Those using the model will be able to establish an appropriate development path, communicate strategy and vision, and assess current opportunities. The Maturity Model can also serve as a strategic framework for vendors, regulators, and consumers who have or desire a role in creating a smarter grid.

The Maturity Model establishes a series of levels of maturity. Currently, the smart grid is in level one: "Contemplating Smart Grid transformation. May have vision but no strategy yet. Exploring options. Evaluating business cases, technologies. Might have elements already deployed.", which describes the state of the art on research and technologies available.

Although many companies have already developed their own solutions for the Smart Grid, there are still no standardized applications available in the market.

Current Level of Dissemination

There are countless examples of small scale use of the technology described in this use case. This is possible due to the high degree of maturity of ICTs that are used. However the diverse number of stakeholders involved, as well as old-fashioned legislation, that does not take into account of the use of smart grids prevented for its widespread use.

Future Trends

Nowadays, tariffs with only few time periods associated with different energy prices are offered by some utilities companies. For optimisation, it would be more convenient to have a dynamic pricing model that offers more flexibility. This new tariff model is strongly based on exchanges between the utility and buildings in order to develop Active Demand. The dynamic pricing architecture is based on power load forecast on day N-1 for day N. The utility sends on day N-1 a forecast X minutes price signal to the device in charge of processing it for day N. On day N, the utility can re-adjust the previously sent signal by sending another one that takes into account of the supplying condition. Hence, it would offer more solutions for the optimisation process.

11. Standards-based Solutions for Building Life-cycle Management

Scenario

The “Blue Sea” is a hotel chain which is involved in all phases of its hotels life-cycle. This process is supported by a building management tool (BMT), which is based on a standard BIM (Building Information Model). This approach allows taking advantage of all the information that have been generated in previous phases of the building process and keeping it permanently updated, avoiding mistakes and inefficiencies.

When the construction of a new hotel is started, the initial functional requirements of the building are defined by the Blue Sea’s project leader through the BMT. The architect that will design the new hotel can automatically access to this information through his sketching tool. Once the final sketch of the building is agreed, this is imported by the BMT and any changing in the functional requirements of the hotel that were agreed among Blue Sea and the architect is updated. Also this sketch is automatically load by the architectural CAD tool that is used to complete the building design and updating the BIM. BIM is shared between the architect and the engineering teams (building structure, HVAC, electrical and telecommunications installations,...), in such a way that all teams works over the same building version and it is not needed that every one redefine the building to feed his CAD/CAE tool. The interoperability among the different tools through the standard BIM allows doing an exhaustive analysis of the building energy demand and energy consumption, in such a way that the building design and its installations are optimized to achieve the maximum energy efficiency.

Once the building design is finished, the Blue Sea’s BMT is updated with the BIM that supports the building project. All the information about the building and its equipment (qualities and performances, cost, estimated cost....) is updated and accessible through the information system.

At realization stage, the market conditions for windows have change and Blue Sea would like to analyze the viability of adopting low-e double glazing windows, initially rejected due to their high cost. The building energy simulation tool is fed with the BIM, windows are changed to low-e double glazing and a cost-benefit analysis is done to make a decision. This analysis shows that according to the new costs, the initial overcost is affordable and the energy performance of the building is improved. Again, BMT’s BIM is updated with the new windows.

Once the building is finished a maintenance plan has to be defined, but this is not a problem because all the necessary information is in the BIM. When every one of the systems was selected, the relevant information was included, as for example maintenance period, and also the digital catalogues of the manufacturer were linked to access for more detailed information about maintenance operation guides, etc. The availability of a reliable and accessible maintenance plan make possible keeping the initial energy performance of the building along all its useful life

Concept

Energy efficiency in buildings is a topic that requires a holistic management during the life cycle of buildings and involves the “traditional” building sector stakeholders (promoters, builders, facility managers...) and “new” stakeholders in the sector (users, building automation systems...).

In order to make easier and more efficient the interaction among all of them, there are protocols and standards to define the building, taking into account architectural aspects and building installations. The data that are managed by these protocols are generated through CAD/CAE tools. BIMs are the main example of this type of standards. BIMs represent a building as hierarchy of objects that carry their geometry, relations and attributes.

Provided Service

The main service that is provided by these protocols and standards is making possible the interoperability among multiple ICT tools that are used for the design of an energy efficient building, its construction and its accurate maintenance.

The adoption of standards (open or proprietary) makes possible the automatic management and exploitation of data that have been generated by other ICT tools or systems. Higher is the level of consensus of the standard, wider is the community of users and the collection of available tools. The following diagram summarizes the trade off that has to take place between consensus and customization in standard making and reflects the reality facing all organizations that wish to introduce and set standards.

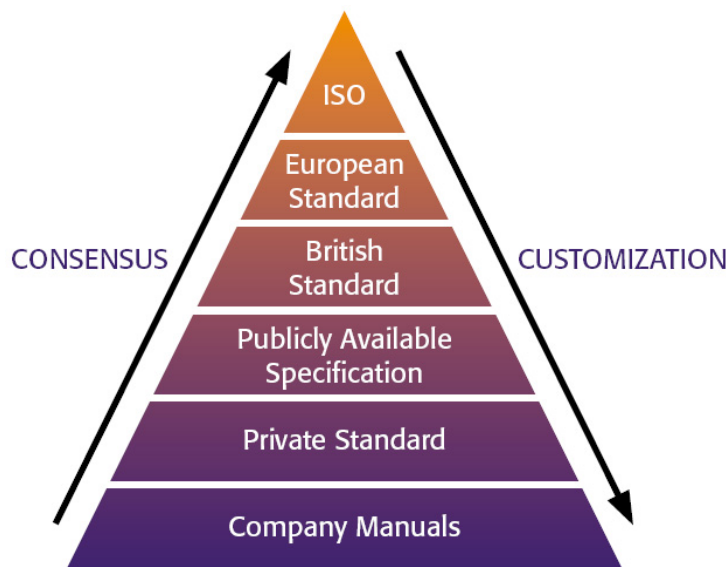


Figure 13: Trade-off between consensus and customization in standard making (Source: Rethinking standards in construction *)

* www.bsigroup.com/upload/Standards%20&%20Publications/Building/Rethinking%20Standards%20Brochure_Final.pdf

In building life cycle high consensus is very relevant, because it is a very long (around 75 years) and dynamic process. This means that a lot of agents will be involved in the process and can not be prefixed. Consequently, as higher is the consensus level of a standard, easier will be finding agents that are familiarized with it.

The adoption of open standards provides an additional advantage in relation to proprietary standards. The first ones avoid the dependency on a specific ICT tool provider and make easier the interoperability with a larger collection of tools.

Impacts

The main impacts of adopting these types of standards are:

- Faster project design and execution. Every agent takes advantage of the information that has been provided by the previous agents in the value chain. Consequently, he can do his task faster.
- Error free projects. Already available information about the building is automatically read by the software tools, without any manipulation by people. Consequently typing and drawing mistakes and misunderstandings are avoided.
- More accurate analysis of the building energy efficiency. The interoperability with building energy efficiency oriented tools makes more affordable the deep analysis of building energy performance during its life cycle
- Reliable and permanently updated information. Good quality and accessible information allows better decision making at any stage of the building life cycle.
- Cheaper buildings. Faster and error free projects means cheaper buildings construction. But the accurate analysis of its life cycle energy performances also means cheaper building exploitation. The NIST (National Institute of Standards and Technology) estimated as \$15.8 billion/year the lack of interoperability costs for the capital facilities industry in 2002. Of these costs, two-thirds are borne by owners and operators, which incur most of these costs during ongoing facility operation and maintenance.

Stakeholders (providers, users)

Taking into account that the main objective of protocols and standards is the interoperability among different ICT applications, the number of stakeholders that are involved is very large. Following, the main stakeholders and their main expectation in relation with this topic are analyzed:

- Building designers. They are interested in standards and protocols that allow automating the information flows among the different ICT tools that are managed in order to design energy efficient buildings: CAD tools, simulation tools, cost analysis tools...
- Building owners and Facility Managers. They are interested in standards and protocols that allow managing all the information about the building that is generated along its life cycle, in such a way that the information is always available and updated.
- Public Organisms. They are interested in obtaining statistics about Energy Efficiency and will be able to promote best practices guides for constructors with advices about the best building solutions.

Maturity

There are available several standards that are competitors among them. From the point of view of BIMs, the main open standard is the Industry Foundation Classes (IFC). It is supported by the

main construction sector software developers, as Autodesk, Nemetschek, Graphisoft, or Bentley Systems. Its definition started more than ten years ago and it is in permanent evolution, keeping its compatibility with previous versions. The last stable version is IFC2x3-TC1, and a beta version of the new release (IFC2x4) is already available. There are also other initiatives, as ISO 12006, but it is not so supported by commercial tools.

However, also proprietary standards have been developed by the large building sector CAD/CAE tools developers, as Autodesk, Nemetschek or Graphisoft. These BIMs are more efficient in terms of file size (binary files instead of ASCII files) and more complete, but fully focus on the tools that are included in the software suite of the developer. For example, the Autodesk REVIT Suite provides interoperability among the Autodesk Revit Architecture (architectural design), Autodesk Revit Structure (structural analysis) Autodesk Revit MEP (mechanical, electrical, and plumbing engineering) tools.

Current Level of Dissemination

The adoption of BIMs have been started by large organizations that need to manage many buildings, as Senate Properties, a government owned enterprise responsible for managing and letting the property assets of the Finnish state. IFC and Autodesk BIM are the most common in Europe.

Future Trends

The future evolution of standards-based solutions for building life-cycle management should be based on the consolidation of IFC BIM open standard. These are the main task to be done:

- Extension of the current BIMs to support all the data that are requested in order to achieve energy efficient building from the initial conceptualization of the building to its maintenance during its exploitation, including embedded energy in building materials, in such a way that a holistic LCA can be deployed in all buildings.
- Database server oriented BIMs. Current BIMs are shared through files. This approach is good enough for sequential interaction, but made very complex the coordination of simultaneous activities.
- Bidirectional IFC compatibility. In several tools, current IFC implementation is not bi-directional. Some tools only export IFC BIM and others only import it. This approach broken the sequence and new data can not be reused in later tasks.

Nevertheless, proprietary BIMs will also have an important role, because the large software developers are following the strategy of extending their original tools with new complementary tools.

12. Standards-based Energy Data Exchange Solutions

Scenario

John is the responsible of maintenance of a SME headquarter, a 600 m² two-storey building. Five years ago, he installed a new Building Energy Management System (BEMS) that is able of controlling the HVAC system of the building and interacting with the electric power supplier. After five years of successful operation, the heat pump fails and has to be replaced. When he calls to the installer to replace it, he is informed that this heat pump is no longer available in the market because the manufacturer crashed one year ago. Initially, he feels very worried in view of the need of replacing the whole system (heat pump, BEMS, fancoils, thermostats...). This would means a new investment of around 60.000 € and disturbing for a long time the activity of the

workers. However, when technician review the specification of the heat pump he realizes that it is compatible with one of the main standards for building automation. This good news dispels the John's fears, because there are several heat pumps in the market that are compatible with this standard. John selects the best one to satisfy the building thermal requirements without doing any additional investment in the rest of systems. Finally, the repair budget is 10.000 €, the HVAC system is running again in just 2 days and a lot of money is saved by John's company and the impact in the workers is minimized.

One year later, a new ESCO is installed in the area and John's company is invited to integrate its building in the smart grid. An important saving in the energy bill could be achieved if the building is integrated in the smart grid. Initially, John is concerned about the changes to be done in the BEMS, but after talking with the ESCO, he realizes that this is using the same communication standard that was used by the current utility and not change is required in the system. Consequently, John's company is integrated in the smart grid and a very important saving in its energy bill is achieved.

Concept

Energy data exchange standards are oriented to manage real time data that allow knowing the building state and its internal and external operation conditions (i.e. energy cost). Consequently, two families of standards and protocols can be identified: protocols oriented to data exchange inside of the building, which have to manage the very detailed data that is requested by the monitoring and control system, and data exchange outside of the building, which have to manage more aggregated data and interchange information between the building and the utility/ESCO and other buildings.

Provided Service

The main service that is provided by the protocols and standards for energy data exchange is making possible the interoperability among multiple sensing and control devices that are related with building energy management (BEM) and the integration of the buildings in smart grids.

Impacts

There are several impacts that are due to the adoption of standards for energy data exchange. These are the main ones:

- Freedom to select the devices that better satisfy your needs.
- Cheaper systems, due to the competitiveness among the multiple suppliers and the reduction of the training costs because only one protocol has to be learned.
- Availability of devices that warranty the future operation of the system and its upgrading.
- Availability of real data about energy performance of buildings, which can be exploited in future buildings design and to aware building users about their high energy consumption in relation with their neighbours' consumption.
- Buildings can be active components of the energy grid. A common standard is required to coordinate the energy consumption/generation of the multiple buildings that are managed by an ESCO.

Stakeholders (providers, users)

Taking into account that the main objective of protocols and standards is the interoperability among different systems, the number of stakeholders that are involved is very large. Following, the main stakeholders and their main expectation in relation with this topic are analyzed:

- Building designers: They are interested in standards and protocols that make possible to foresee the energy consumption of the building at design stage. Consequently, their interest focuses on:
 - *Availability of real data about energy consumption in buildings*. The accurate (detailed energy consumption per load type) and contextualized (building characterization, usage conditions, weather conditions...) collection of data about energy consumption in existing buildings is very useful knowledge to increase the energy performance of new buildings.
- Building users and building operators. They are interested in standards and protocols that make easier and understandable the building operation and maintenance. Consequently, their interest focuses on:
 - *Plug&play facilities*. Standards that make possible connecting and removing devices without need of manual reconfiguration of the system.
 - *Backward compatibility*. Standards that make possible replacement of existing devices by new ones, but without need of updating the whole system.
- Installers. They are interested in standards and protocols that make easier the maintenance and updating of the building systems. Consequently, their interest matches with the interests of “building users and building operators” (*Plug&play facilities*, *Backward compatibility* and *BIMs*), but they have an additional one:
 - *Protocols and standards for auto-testing*. Testing of BEMs is a very boring and time consuming task. Consequently, testing protocols and standards that simplify and automate this task are very relevant for these stakeholders.
- Utilities and ESCOs. They are interested in standards and protocols that make possible knowing the current energy consumption/generation in the building, its capacity to adapt to the network constraints and their expected energy consumption/generation for the next control periods. Consequently, their interest focuses on:
 - *Protocols and standards for demand management oriented services*
 - *Protocols and standards for local generation management oriented services*
- Local government: They are interested in defining policies and strategic plans to increase the energy efficiency of buildings and neighbourhoods. Consequently, their interest focuses on:
 - *Protocols and standards for monitoring energy consumption in buildings*. Monitoring of energy consumption in buildings makes possible the development of innovative policies to push building owners to reduce energy consumption (i.e, linking building taxes to the energy consumption - in some Italian cities the garbage collection taxes are fixed according to the garbage that is generated) and prioritizing their investments in energy efficiency oriented refurbishment programs.

Maturity

In relation with standards for building control and monitoring, we could say that there is “over” standardization, in the sense that exist several standards (open standards and “de-facto” proprietary standards) for similar purposes. X10 was the first open standard, defined in 1975, but nowadays the main references are two open standards: KNX and LONWORKS, which are compatible with multiple physical layers. Also a large collection of proprietary protocols have been developed during the last year, as IHC in Denmark, Teletask in Belgium, Deltadore in France, Ingenium, Maxdomo and Vivimat in Spain, ... However, a convergence process has been initiated (i.e. KNX is the result of merging three previous standards: BatiBus, EIB and EHS) and many of the manufacturers that developed the proprietary protocols during the last decade are migrating toward KNX and LONWORKS or are developing gateways to these standards.

However, in relation with “outside building” energy data exchange protocols the situation is completely different. This is a new domain and the standards for data exchange are being developed. There are two main initiatives, both based on open standards: the extension of the standard IEC 61850, which was originally defined for the automation of electrical substations, to support the integration of buildings in the smart grid and DLMS-COSEM, common language for Automatic Meter Reading, or more general, Demand Side Management.

Current Level of Dissemination

The level of dissemination of every type of standards is very different.

In relation with building control and monitoring protocols, they are very common in new and refurbished office buildings, but in residential building they are only present in high level new buildings. KNX could be considered as the main reference in Europe and LONWORKS could be considered as the main the main one in North America.

“Outside building” energy data exchange protocols are not common in Europe yet. Smart meters are in operation only in Italy.

Future Trends

The future evolution of protocols and standards for energy data exchange should address the following objectives:

- Dynamic discovery of prosumer devices and implicit integration. The configuration of the BEM has to be automated in such a way that manual activities are minimized.
- P2P versus centralized exchange of info. The increasing intelligence of every component of future control systems will require the evolution toward protocols that make possible the direct communication among them. This approach should be extended from Device2Device communications (inside building) to building2building communications (outside building).
- Security (privacy, authentication, data encapsulation ...) for “outside” building protocols and standards. Current protocols are robust and reliable and have been used for data exchange through private networks. However, the evolution toward public IP networks and the increasing number of these data will require that current standards are enhanced with capabilities to warranty privacy and authentication of the data.
- Integration of protocols from different fields. Current protocols are oriented to specific domains. For example, KNX and LONWORKS are general purpose monitoring and control oriented standards while IEEE 1394 (commercially known as FireWire or i.Link) is a communication standard for A/V (audio/visual) component communication and control. The integration off all devices in a house in a unified control system should be supported by the integration of already existing standards for every domain, avoiding the apparition of new standards that would duplicate the existing ones.
- Normalization of data for easy comparison among buildings. The current “outside building” energy data exchange protocols will have to be enhanced to include the requested information that make possible comparing and analyzing the energy performance of several buildings, existing or at design stage.
- Evolution of current “current status” oriented protocols to “forecasted status” oriented ones. Current control and energy management systems only take into account the current building and energy network state, but future systems will define their control strategies taking into account the expected evolution of the building energy demand/generation.
- Definition of energy supply status for building operation. The selection of the most sustainable energy management strategy in a building will require that communication

protocols allow to the utility/ESCO sending detailed information about the energy that is being provided: cost and CO₂ emissions per kWh.

As a global future trend, the development of all these needed functionalities should be achieved through the evolution and convergence of existing standards and protocols, instead of by the definition of new ones.

Gap Analysis

Research and Technology
Development Activities

Gap Analysis of Research and Technology Development Activities

While world and Europe in particular is facing very serious challenges requiring strict energy usage control and the development of innovative ideas and technologies to support this strict regime, we cannot ignore the positive research and innovations tendency in ICT development cluster. Inspiration and novelty are key issues for most of the ongoing research activities of the last decade, in part due to efforts of the European Union, European researching organisations and EU-member states. To take advantage of these innovations, it is necessary to evaluate the challenges we face and take stock of the innovative methodologies in Research and Technology Development (RTD) intended to deal with these challenges.

Outlining the RTD activities

To better understand the portfolio of RTD activities related to ICT for energy efficient buildings, more than 270 related projects worldwide were scanned, and 52 were selected for deep analysis and development of Categorization criteria. Five Main Classification Categories (MCC) were identified and consolidated. The names and numbering for these five MCC were:

- (I) Energy Efficient (EE) design & production management;
- (II) Intelligent & integrated control;
- (III) User awareness & decision support;
- (IV) Energy management & trading;
- (V) Integration Technologies.

Qualitative and Quantitative Gap Analysis of selected RTD per developed Main Classification Category (MCC), type and nature of research participants, including the research cartography analysis and recommendations are presented in following sections.

The Challenges and Objectives of Gap Analysis

This RTD Gap Analysis identifies major challenges in:

- Uneven distribution of ICT for energy efficient buildings related research activities in the different European countries and states as well as the number of participating entities in these countries;
- There are also major gaps in knowledge sharing capability in industry and research domains. Dissemination of RTD results resources is not widely used;
- The recognition of ICT as a social technology, so it will enable such energy-consumer behaviour when user awareness, control feedback and use of intelligence tools become important. It is therefore necessary that social aspects should be addressed in such areas as technology perception, acceptance and impacts.

While the previous chapter compared the different Best Practices to develop the best management practice guide, the objectives of this RTD Gap Analysis is to identify the missing elements and assess their impacts on the innovation agenda.

The specific objectives are:

- To identify the most essential areas and directions for further research in the “ICT for EEB” domain (i.e. Qualitative Gap Analysis);
- To involve more EU member states, public and private research organisations and industry etc. into ICT for EEB related RTD activities (using results of Quantitative Gap Analysis).
- Set out a long-term energy research, demonstration and innovation agenda(through identification of research challenges);

Approach to the Gap Analysis

The following outlines the methodology adopted to carry out the RTD Gap Analysis:

- After the detailed selection and deep analysis of those researching activities related to “ICT for Energy Efficiency (EE) in Buildings”, a **Qualitative** RTD Gap Analysis was carried out. The aim was not only to describe the Main Classification Categories (MCC) and allocate RTD projects within these categories, but also to identify and evaluate the weak/non-covered areas in each of the category.
- The **Quantitative** Gap Analysis is identifying the distribution of researching projects within the EU and worldwide by several major parameters. The resulting **Cartography** can be used towards the dissemination of European initiatives for blueprint of affordable, clean, efficient and low-emission energy technologies.
- From the Qualitative and Quantitative analyses, the research challenges were defined. These identified challenges for each of MCC were evaluated and assessed against opportunities in ICT sector to develop the research gaps recovery.

The Qualitative Gap Analysis of selected RTD per Main Classification Category (MCC)

The Qualitative Gap Analysis provides an indication of the areas of interest moving researching activities forward.

Distribution of Projects across MCC

The overall distribution across the Main Classification Categories (MCC) is quite even and ranges from 16% to 19% - except for MCC (II) “Intelligent and Integrated Control” which has a share of 32% of all projects.

Description of MCC:

- (I) EE Design and Production Management;
- (II) Intelligent and Integrated Control;
- (III) User Awareness and Decision Support;
- (IV) Energy Management and Trading;
- (V) Integration Technologies.

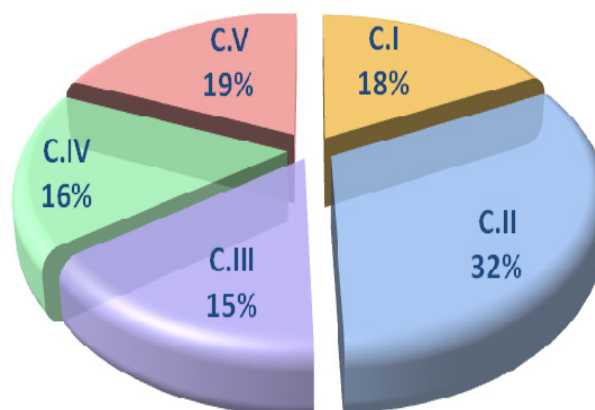


Figure 14: Total percentage distribution of selected RTD per MCC I – V

I. Energy Efficient Design & Production Management [MCC (I)]

This category includes RTD activities focusing on the development of:

- Advanced Design Support Tools and Design Integration;
- Knowledge Sharing and Production Management, as well as
- Advanced Simulation and Modelling Tools.

The detailed structure of this category and related sub-categories is presented in the following figure.

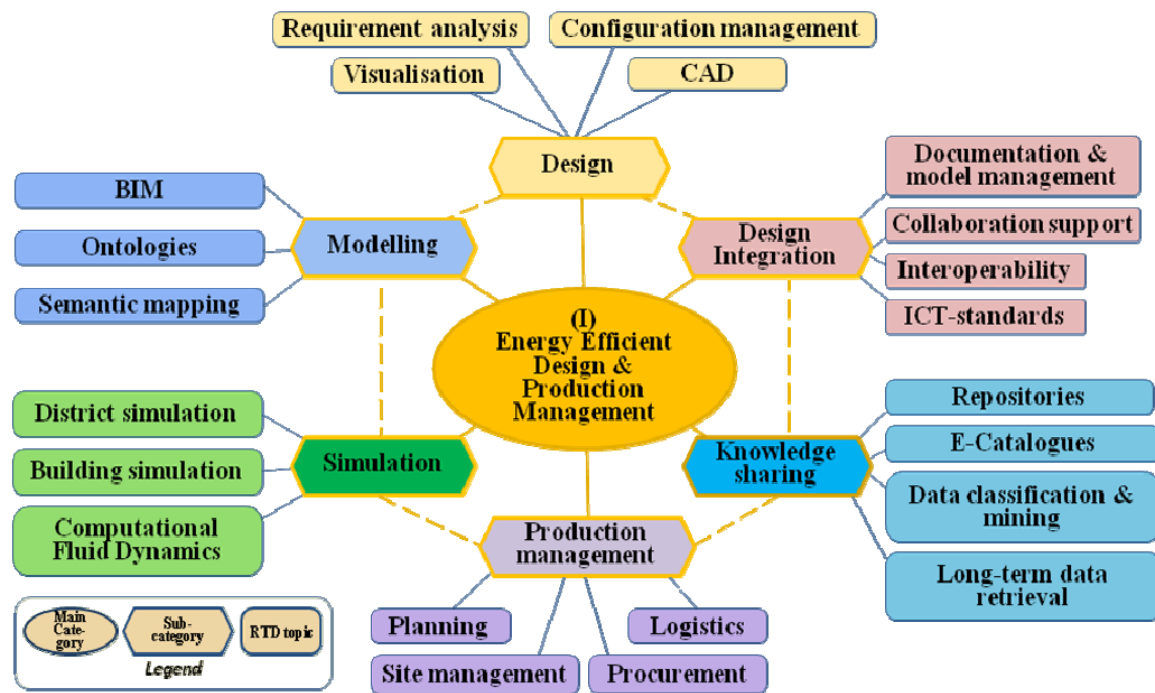


Figure 15: MCC (I) – Energy Efficient Design and Production Management

SC I.1 Design: Research activities are concentrated on the development of computer aided solutions to support the design of integrated systems. Innovative design principles, such as feature based or parametric design, should be adapted into cross-disciplinary solutions allowing the propagation of design changes across multiple domain-specific CAD applications.

Secondly, improved visualisation capabilities are required to enable engineers and customers to easily understand the impacts and complexity of design changes and to visualise the interaction of high-performance components.

Currently, the capability of CAD-systems to support Early Design Stages is limited, since most systems require detailed model development. Furthermore, the appropriate documentation of clients' requirements profiles, including their analysis with sparsely or incomplete models needs to be improved.

SC I.2 Design Integration: This RTD area focuses on the development of integrated systems documentation and model management of complete systems instead of individual (sub)systems and components. This could be achieved through the introduction of collaboration support and interoperability.

The introduction of globally accepted standards for systems and building modelling is envisaged and highly recommended. The emphasis should be on the extension of existing standards, such as IFC or gbXML; to allow the consistent and integrated management of “energy-related information” as part of these standards.

Furthermore, it is required to better support the production, supply-chain management, and assembly of pre-fabricated systems and components. The large-scale introduction of RFID-technology could contribute to efficiency gains in Production Management and Collaboration Support.

Finally, it is important to close the gap between “CA-model management” and “as-built documentation”. Again, a decentralised information management approach using RFID technology could improve the documentation of complex engineering systems since installed parts and components can be clearly identified and links to digital product and manufacturing documentation can be easier tracked and established.

SC I.3 Knowledge Sharing: RTD activities within this subcategory comprise the development of the integrated repositories, sophisticated e-catalogues, advanced algorithms for data classification and mining, and long-term data retrieval.

Whereas recent and current research has focused on the development of integrated repositories and e-catalogues future research should include the development of classification and data mining strategies for (sensed and metered) building performances data.

It is essential that more efforts are invested in the development of advanced, integrated platforms for the multi-dimensional management and prolonged measurement of (sensed and metered) building performance data.

SC I.4 Production Management: RTD activities in this area have focused on the development of tools to improve the efficiency of production planning, procurement, logistics, site management etc; Recent projects focused on the development of holistic planning solution, including advanced options for procurement management.

Future research in this area should focus on the development of integrated production management tools which are included with construction logistics solutions for the renovation of buildings in urban, densely populated areas. The paradigm of “Just-in-sequence” logistics management needs to be adapted to the constraints of construction management.

SC I.5 Simulation: Recent R&D activities focused on the development of Energy Simulation Packages to support the design phase. Only a limited number of simulation tools support energy-simulations in early design phases. Furthermore, ad-hoc energy-simulations to adjust and calibrate “life” control algorithm during “run-time” are not available. Finally, modelling and processing capabilities of energy simulation tools are usually limited to so called “conventional systems”. Renewable sources and innovative systems, such as low temperature heating systems, are not supported by all tools.

Therefore, future research in this area should focus on the development of integrated building simulation tools, the development of tools for demand/supply simulation in energy distribution systems on district scale, and the expansion of the modelling capabilities for CFD-tools.

SC I.6 Modelling: Past and recent research in this area has focused on the development of Ontology and Semantic Mapping. This research made a substantial contribution towards Systems Interoperability and Design Integration. Research findings were used to progress with the development of Building Information Models (BIM).

However, current BIM still has a limited capacity to support Energy-Modelling and Energy Simulation. Therefore it is essential to use the available, well advanced knowledge in Ontology and Semantic Mapping to extend the “Model Scope” of BIM towards “energy attributes” and the management of features to be modelled for Building Automation and Control.

Finally, it is essential to develop an approach that allows the integrated access of BIM-data and data to document the building performance history.

II. Intelligent and Integrated Control [MCC II]

This category contains RTD activities focusing on the development and implementation of meshed, self-adaptable and easy to install sensor networks (i.e. hardware and software, operating systems and protocols), development of automation and control technologies, improved diagnostics, performance data analysis, smart metering and actuation, intelligent and predictive control systems etc.

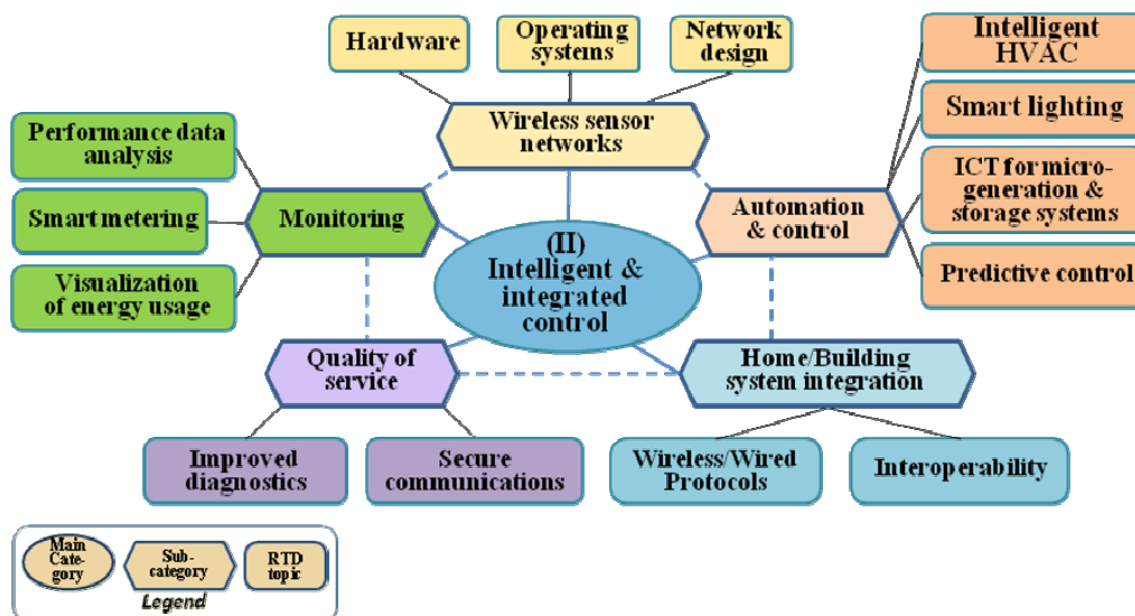


Figure 16: MCC (II) - Intelligent and Integrated Control

SC II.1 Wireless Sensor Networks: Researching projects dealing with networks of wireless sensors and actuators enabling all energy systems and indoor/outdoor conditions measurement devices to communicate and share energy related information. Selected RTD activities include:

- Hardware: Systems and Equipment for energy use/production/storage: integration of advanced components: sensors, actuators, suitable intelligent power electronics and controls systems, interfacing with energy management systems.
- Operating Systems - Dynamic control & (re-)configuration of devices: Research focuses on the development of algorithms and architectures for any configuration of smart devices to be able to dynamically evolve according to the environment or change in a choice of a global strategy. This includes as well individual “roaming” profiling, allowing configurations to follow users, related to a wide variety of applications, putting to the extreme the concept of roaming of services in the context of automation for maintenance / repairing.
- Network design for Plug & Play: Based on open, IP-based protocols enabling all systems to share information, e.g. each new component in a building is automatically discovered as well as its primitive functions for information access. The principle would be the same at neighbourhood level, where each new building or each new energy generation unit would be detected and seamlessly integrated in the district energy network.

SC II.2 Automation and Control: RTD focuses on systems development of modular, easily customisable systems with configuration tools, adaptive and able to learn from their environment. The built environments can react to their environment and to users' needs and behaviour proactively, e.g. as a combination of predictive control, intelligent HVAC, intelligent lighting.

Intelligent HVAC: development of Building Energy Management Systems (BEMS) with automation and self-adaptation to changing operational conditions of the buildings, including building/grid energy balancing;

Smart Lighting: development of new light sources (e.g. (O)LED, compact fluorescent technologies), ICT-enhanced lighting control (through occupancy sensors, daylight and ambient light sensors, dimming systems);

ICT for micro-generation & storage systems: development of innovative and replicable architectures allowing the integration/management of all kinds of (renewable) energy sources, to optimise the local distributed production and storage of energy and to dynamically use the energy requested in various parts of a building in different contexts (e.g. user profiling, security level, etc.);

Predictive control: to predict maintenance, to diagnose failures, to optimize components' performance; (e.g. advanced HVAC & lighting controls are able to adjust the level of service to the energy and comfort constraints - providing at the same time a higher degree of occupant comfort and indoor air quality);

SC II.3 Home/Building System Integration: In this sub-category selected RTDs should develop interoperable connections and protocols allowing holistic provision, operation, monitoring and maintenance of systems (e.g. various control and service software will run on a common integration platform, a "building operation system"). Various building services [heating, cooling, lighting, air-conditioning, security etc.], which are currently often operated independently, will be managed holistically.

Protocols: Open, IP-based protocol enabling HVAC, lighting, FL&S and security, occupancy and badge data systems to share information achieving enhanced operation and efficiency (e.g. wired protocols, wireless protocols);

Interoperability: this includes RTD focusing on the development of advanced tools which are aiming to improve the interoperability of monitoring, control, (home) entertainment, security, access control and other systems into one consistent, integrated control environment.

This requires research on communication standards, (hierarchical) models to support the integration of buildings, distribution and smart grids; from single part to whole buildings to groups of buildings, to districts, to cities, etc.);

Architecture should provide mechanisms to deal with the management of local coordination of energy systems, while at the same time ensuring appropriate integration with smart energy grids - including securing the energy provision at any time.

SC II.4 Quality of Service: this sub-category includes the following RTD:

Improved diagnostics for efficient optimisation/improvement of

- Information processing (estimation of bias, reliability of sensors), tools for detecting abnormal consumption, diagnosis for maintenance (new solutions for automated or continuous commissioning including diagnosing malfunctioning sensors, actuators, valves, etc.); and
- ICT tools for diagnostic and renovation of existing buildings and infrastructures as well as elements of the buildings (primarily envelope, but also appliances in the building for lighting,

heating, ventilation) - especially if relying on global optimisation techniques & software tools (GA, neuronal networks, etc.);

Secure communications: developed concepts of the project could be implemented where it is necessary to make all components and systems communicate through the building. Either wired or wireless, separated between voice and data backbone and building automation system or using the same infrastructure, but able to guarantee data security when voice and data networks are interconnected with building management systems;

SC II.5 Monitoring: through smart metering, visualisation of energy usage and performance data analysis, all stakeholders (users, energy providers, energy managers) are able to visualise and analyse energy consumption in real-time, take appropriate measures and/or propose adapted services.

Performance data analysis: models for theoretical performance & estimation of energy consumption, tools for energy use evaluation & models updating;

Smart metering: models for communicating meters, interoperation between (networks of) smart meter(s) and (energy providers) information systems. Tools for recording real-time energy use and making that information available through a software interface, which acts as a bridge between the "smart building" and the "smart grid", making demand-response processes available;

Visualisation (of energy usage): behaviour modelling, interface monitoring & intuitive feedback to users on real time energy consumption in order to change behaviour on energy-intensive systems usage (this could reduce 5-15% of energy consumption).

III. User Awareness and Decision Support [MCC III]

The RTD activities, which have been selected within this category, focus on improved analysis of building's EE performance data and visualisation of this data for better management assessment.

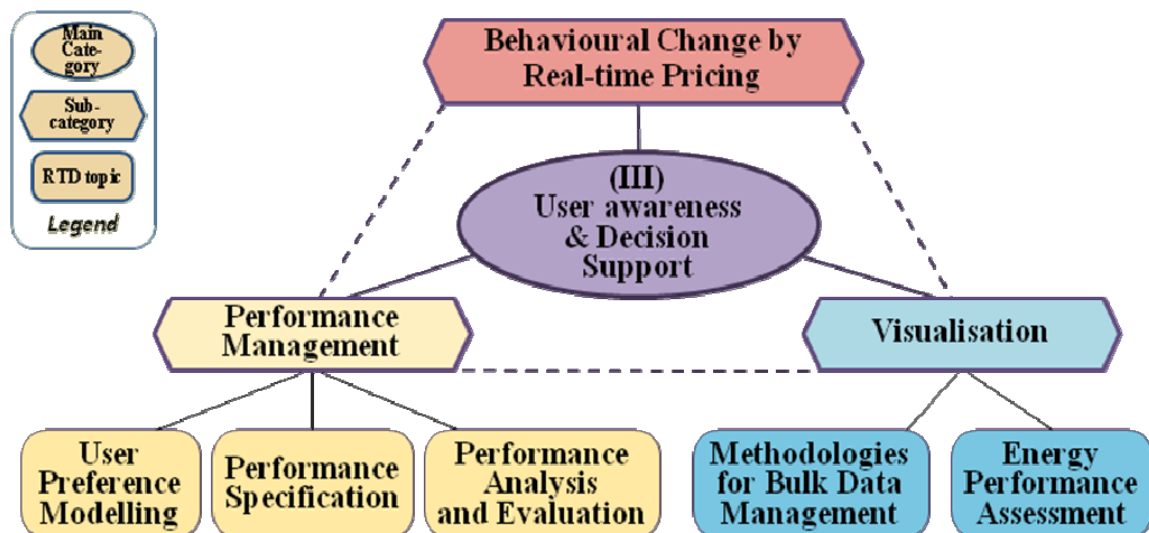


Figure 17: MCC (III) - User Awareness and Decision Support

SC III.1 Performance Management: Research in this area focuses on the integrated modelling and analysis of: (1) User Preferences, (2) Performance Specification and (3) Performance Analysis and Evaluation.

Recent research in AI has focused on the (general) modelling of user preferences. However, there are a very limited number of systems for user preference modelling for HVAC and lighting systems available. In terms of performance specification there exist numerous national

regulations. Furthermore, the number of tools supporting the evaluation of these performance specifications is limited. Knowledge and information exchange across national borders is limited. Last but not least many commercial Building Management Systems support trivial performance analysis functions. Complex, multi-criteria analysis functions are seldom available and need to be developed. Finally, it is important that Performance Specification tools can be easily integrated with design and decision support tools.

SC III.2 Visualisation: Research focuses on the development of simple, easy understandable and comparable mechanisms for the visualisation of energy performance data. So far, little research was performed to explore and identify the (advanced) information needs of the individual stakeholders, such as tenants, building operators, building owners, ESCO, etc.

Firstly, it is essential to develop information processing strategies which support the context-sensitive aggregation of bulk performance data to provide individual stakeholders with an appropriate granularity of building performance data.

Secondly, it is important to allow the end user to compare the aggregated energy performance data with that of other users and – more importantly – to allow the evaluation of consumption data with performance standards, ratings, and classifications to increase the level of awareness.

Finally, it should be possible to use aggregated performance data for ratings and performance assessments.

SC III.3 Behavioural change by real-time pricing: this sub-category was introduced for those projects, which allow individual users to visualise their consumption patterns and adopt appropriate measures for energy savings due to behavioural changes.

Behavioural change will be stimulated by “real-time” pricing. So far, the business model of “real-time pricing” in the residential market is only used in a few regions, such as in California. It is more common in business models offered to “bulk” energy consumers in industry.

To support real-time pricing smart meters must be installed as a prerequisite. Additionally, it is essential that end-users are seamlessly provided with easy understandable overall consumption data. Additionally, it is required that users can choose between different options how to adjust their current behaviours “real time”.

Sub-metering and interoperable information exchange between sub-meters and major consumers (end-devices) is required. Currently, we are lacking appropriate business models to stimulate information exchange about demand/supply profiles. Finally, it is essential that commonly agreed standards are developed describing how to exchange energy-related information.

IV. Energy Management and Trading [MCC IV]

This MCC includes the RTD development of methodologies and tools for efficient energy management on all levels (e.g. urban, district, grid, building, room, area)

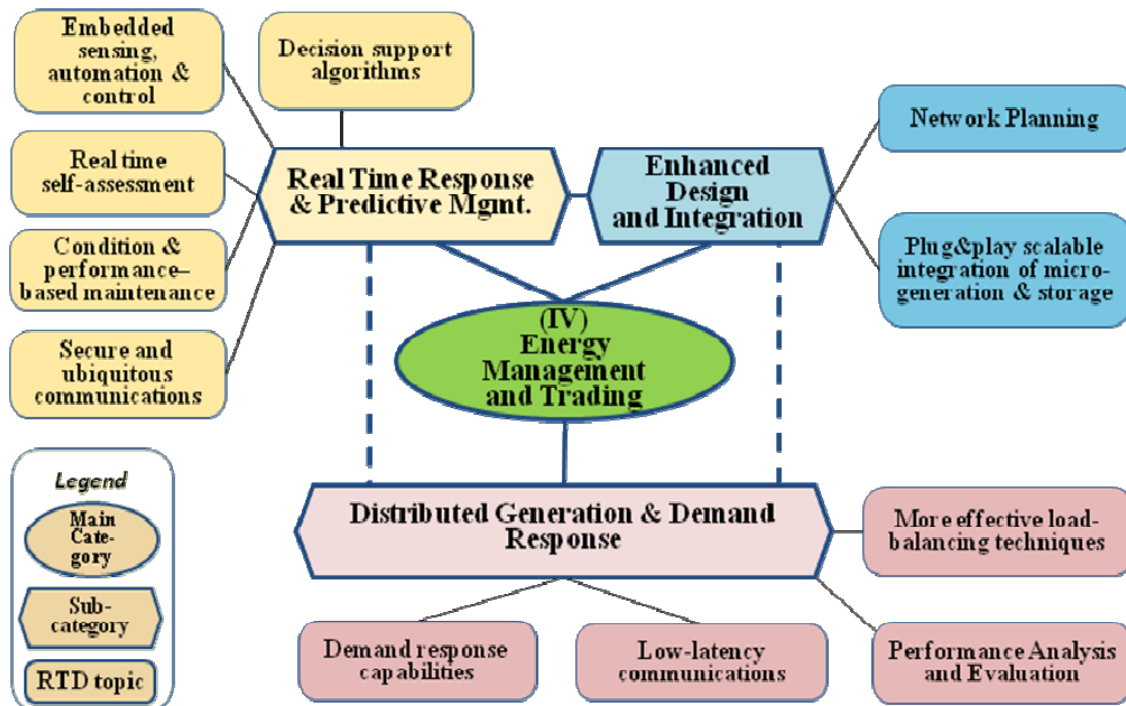


Figure 18: MCC (IV) - Energy Management and Trading

SC IV.1 Real-time response and Predictive Management: By extending the smart grid within the home consumer appliances and devices can be controlled remotely, allowing for demand response. Furthermore, the total “demand profile” could be accumulated by requesting the demand profiles from the individual “energy consumption devices”. Finally, advanced decision support algorithms would enable the individual devices to decide if energy consumption could be minimised or “cut off” for a dedicated time.

Embedded sensing, automation and control: Substantial research is ongoing in the area of Networked Embedded Systems Research. Most of the ongoing past and recent research is ongoing on “general systems” level. A sector specific deployment on “large scale” is still pending. However, this seems to be not a research oriented activity but more a commercialisation activity.

Secure, ubiquitous communications: In the event of a peak in demand, a central system operator would potentially be able to control both the amount of power generation feeding into the system and the amount of demand drawing from the system. However, the pre-requisite is that devices can communicate with each other on the appropriate systems level; e.g. on apartment level, on building level, on district grid level, etc. Research in the area of “The Internet of Things” is clearly supporting this goal. However, there exist a deficit in standardising communication protocols between “White Goods” and “conventional” BMS components. This deficit needs to be addressed in future R&D activities.

Decision Support Algorithms: Research in this area is essential to deliver the right level of software support for the development of decentralised metering and control. Basic achievements of AI-research can be used and customised for R&D in this area. Future research should focus on the adaptation of basic AI-models to the constraints of newly developed business models for “Real-Time Energy Trading”.

Real Time Self Assessment: The availability of consumption data on ‘item level’ would allow for a ‘transparent’ energy consumption overview in ‘real-time’. However, low-cost control and metering capability is currently not available in most of the end-user devices. Additionally, it needs further research to specify privacy issues in terms of detailed energy sub-metering. Finally, there is a need for the development of ‘local data management centres’ to be easily installed in households and to be safely and protected be retrieved by third parties.

SC IV.2 Enhanced Design and Integration: Simplified interconnection standards, two-way power flow capabilities and more effective load balancing techniques can allow distributed generation and energy storage to be incorporated seamlessly into the transmission and distribution network.

Network Planning: Work in this area is not a “core activity” of the construction sector. However, it is recommended to launch “cross-sectoral” projects which would stimulate “Knowledge Transfer” amongst the “Energy Sector” and the “Construction Sector” to enable representatives from both sectors to better understand the “advanced requirements” for interface design which will impact the overall network planning.

Plug and Play scalable integration of micro-generation and storage: Past and recent research has focused on the development of dedicated storage capacities to optimise the functionality of single systems, such as the development of seasonal storages for Solar Heating. However, limited efforts were invested to develop an integrated management of storage capacities in buildings. Therefore, it is recommended that future research should emphasize on the development of complex systems modelling and the related specification of relevant interfaces required for systems and components.

SC IV.3 Distributed Generation and Demand Response: this sub-category emphasises on the development of IT-system supporting an integrated, systemic control of renewable, distributed devices for energy generation and storage.

Load Balancing Techniques: So far, energy was required to operate buildings. Past and recent research has focused on the integration of additional, single renewable energy sources into the buildings’ energy system. Some work has been done to develop advanced control devices for photovoltaic systems.

Demand Response Capabilities: The integrated control of local energy generation in combination with complementing energy storage capacity has been less intensively explored. However, the intelligent control of energy storage capacities is essential to establish additional ‘demand response capabilities’ on local level.

It is recommended that future research focuses on the development of advanced control systems managing distributed energy generation devices and the complementing storage systems in a holistic, integrated way. Emphasis should be given on the development of decision support tools enabling tenants, owners and operators of buildings to decide when to sell energy to the grid, when and how to store locally generated energy, when to buy energy from the grid, or if it is possible to re-schedule energy demand.

Performance Analysis and Evaluation: Past and recent research has been based on the assumption that Smart Metering is available. New business models for flexible tariffs – mostly for industry -were developed. However, there is still a deficit in “sub-metering” within buildings. There is little knowledge available about “real-time” energy profiling. Work can be built on research achievement in multi-dimensional information analysis developed in other sectors, such as retail.

Future research should focus on the adaptation of methodologies for multi-dimensional analysis and evaluation to the needs of the Energy and Facilities Management sector considering the constraints given for Building Performance Data analysis, such as long-term measurement, geographical influence, seasonal influence, etc.

Low-latency communications: The efficient control of distributed energy generation requires fast and efficient communication between the generation devices, the control systems, the ‘consumers’ and potential storage devices. So far, ‘centralised’ control was the preferred strategy for grid operation and Building Management. Through the introduction of a significant higher number of sensors, actuators, generators, and storage devices it becomes essential to develop ‘distributed control strategies’ which will (pre)-process information locally and only exchange relevant information and ‘cross-system’ control signals globally. Future research should focus on the development of ‘cascading’ strategies for information processing in dynamic data and control networks.

V. Integration Technologies [MCC V]

This category describes R&D activities to develop the technological layers for the infrastructure, both hardware and software, which support the acquisition, transmission, exchange, storage, retrieval and presentation of building performance data. We consider this category as a composition of technological subcategories or layers. Additionally, we consider R&D activities to develop tools which support the design and installation of wireless sensor, meter and actuator networks in buildings.

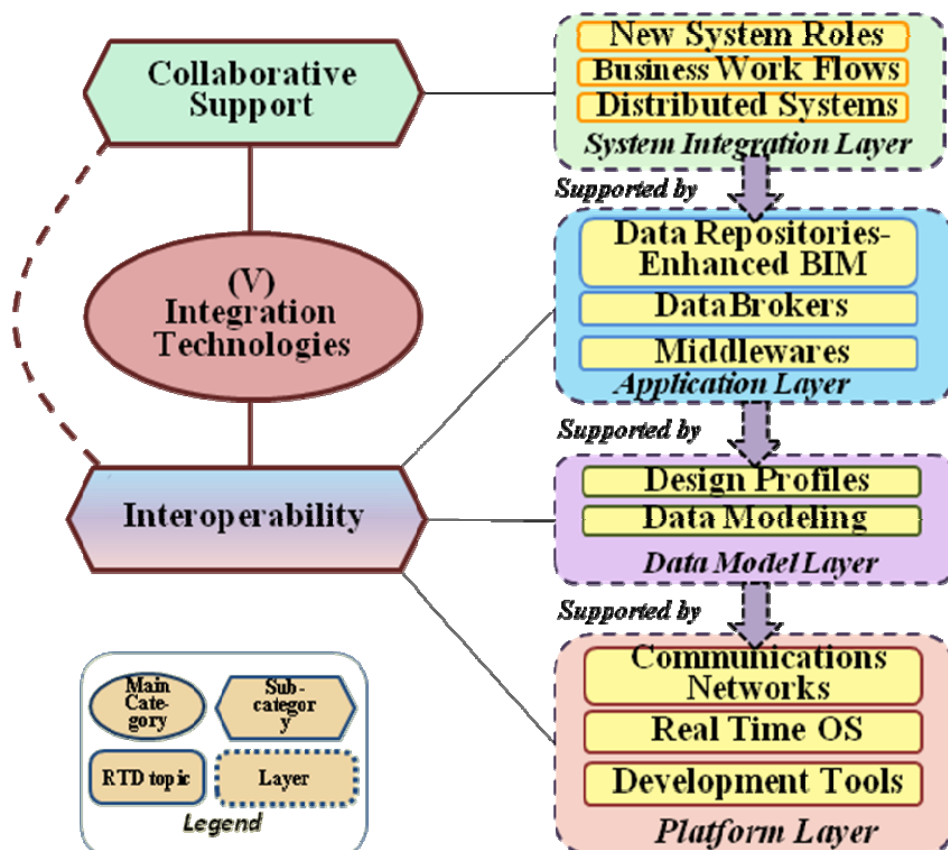


Figure 19: MCC (V) – Integration Technologies

SC V.1 Collaboration Support: R&D activities in this category emphasise on the development of the integration and interoperability framework to support collaboration amongst different stakeholders involved in Energy Management.

System Integration Layer: With the increasing complexity of energy management systems on building and distribution grid level new Business Models are under development. Recent work focuses on the development of so called Energy Service Companies (ESCO). New system roles, workflow specifications and underlying, supportive IT-systems will appear in the Energy Management world. *New System Roles* need to be defined, specifying privileges and constraints for different actors. These will need to be agreed with governance structures/official legislation. It is recommended to specify new *Business Work Flows* to define required data exchange policies amongst different stakeholder, such as the definition of the required energy trading protocols. Finally, it is required to develop *Distributed Systems* to support the newly defined Business Work Flows. These systems should be based on distributed agents deployed to perform a collaborative work. Potential technologies are: Service Orientate Applications; Distributed Data Base applications; Lightweight Directory Access Protocol (LDAP) applications.

SC V.2 Interoperability: This subcategory bundles R&D activities to develop software platforms, the required middleware and Data Management Layer, and the basic hardware/software platform itself.

Applications Layer: A new family of applications will appear in the energy management in buildings scenarios using wireless sensing, metering, and actuation components. New middleware's for data exchange, data repositories, or data brokers that act as message routers and gateways will be required to support those new applications. Data Repositories will include enhanced BIM (Building Information Models).

Data Model Layer: Past and recent research has focused on the development of sector-specific data modelling approaches for the Construction, Energy and ICT sector. An approach for integrated data modelling is not available. Harmonisation in data modelling is a required R&D activity. It is recommended to emphasise on the modelling of design, demand, and supply profiles to better support the cross-sector model integration.

Platform Layer: Comprises R&D tasks in the fields of new low power hardware devices with higher computational power to run not only measurement/control tasks, but more complex routines such as predictive algorithms, or bigger data TX/RX ratios. This layer includes, potentially, the development of new OS (Operating System) that will require less energy consumption of the hardware components and will support advanced decentralise data processing functionalities to enable distributed control scenarios.

Research Challenges

Future decisions about the direction of European research activities in the area of ICT for Energy-Efficiency in Buildings could be based on the analysis of aims and results of most recent and current projects which have been evaluated. The following proposed research areas are identified as a summary of RTD Gap Analysis:

(MCC I) Energy Efficient Design and Production Management, including:

- Design Profiles / Archetypes: There is a need to better support energy simulation in early design stages.
- Design Integration through Standards: A need for standardized models to exchange and manage 'energy-related' information in BIM was identified. Furthermore, we have identified the need for advanced simulation tools, allowing the modelling of renewable energy sources, advanced HVAC components, passive and active storage capacities, etc.
- Knowledge Sharing: amongst the different stakeholders, especially with SME, was identified as important research task.

- Decentralised Information Management and Supply Chain Management (SCM): Energy systems in buildings use many pre-manufactured components. A need for decentralised information management to better support SCM, assembly, and maintenance was identified. R&D is also required to support “just-in-sequence” delivery in renovation projects in “Urban Settings”. These activities are ‘secondary’ support actions.
- The identification of explicitly efficient architectural and engineering approaches from design, production, installation, and to the service/support techniques, should be taken as a main targets of future research projects. For example, development of a novel CAD tool which supports design of a wireless SI with respect to radio propagation, node placement, localisation and reliability as well as supporting simplicity of installation on site, will provide significant positive impact on energy efficiency in buildings. Furthermore design of a BMS architecture that will support combination of services with managed operations across several administrative (e.g. end-user, BMS-operator, owner of building) and business domains (e.g. service providers/suppliers, facility managers, network operators), will cover existing industrial demand for dynamic, re-configurable building service architectures.

(MCC II) Intelligent and Integrated Control, including:

- Integrated Management of Monitoring Data: A deficit for advanced concepts for ‘Multi-dimensional Bulk Data Management and Data Analysis’ was identified and needs to be addressed in future research..
- Middleware: New middleware to facilitate interoperability amongst different devices will be needed.
- Adoption of common, open architecture and advanced control protocols for communication platforms still provides a big challenge for further investigation. Development of power-efficient network protocol infrastructures which are suitable for supporting the middleware will greatly improve efficiency of energy management systems and dynamic service compositions.
- Innovative Wireless Sensing, Metering Components: A need for robust energy management/energy harvesting and customised packaging was identified, to allow ‘long-term’, maintenance free operation in buildings. New hardware and functionalities will require more powerful firmware, which should evolve from proprietary OS to standardised ones to support easy, plug & play installation.
- Systems Integration / Communication Networks: Additional options to support new communication features will have to be added to existing communication devices. Some examples of new features:
 - (1) Wide band Programmable Logic Controller (PLC) interfaces;
 - (2) New Virtual Private Network (VPN) embedded interfaces;
 - (3) Low Power communication interfaces.
- Development Tools: As wireless components are penetrating the market, new development tools for wireless networks will be needed, such as Integrated Development Environments (IDEs) to allow easy, plug & play installation.
- It is also necessary to pay additional attention to improvement of building Sensing Infrastructures (SI) by development of seamless and dynamic end-to-end network compositions and service operations based on a wide range of components from sensor nodes, to Wi-Fi devices, RFID tags and readers. The development of a flexible wireless SI with

modern, miniaturised (but still automatic) sensor nodes (e.g. embedded into the building fabric), will greatly improve self-configuration, self-optimising, and self-healing of such an infrastructure. This includes development and analysis of effective miniaturisation and packaging approaches for next generation of sensor nodes to allow embedding into the building fabric and investigation of effective node energy management techniques.

(MCC III) User Awareness and Decision Support, including:

- Web-Interfaces for Consumption Analysis: A need for the development of robust, easy understandable, (web-based) user interfaces to access and analyse building performance data in a context-sensitive way was identified.
- Data-Brokers: As new stakeholders/actors will be involved in the information flows new Decision Support algorithms will be needed. The use of E-Data-brokers is foreseen for these tasks.
- Exploitation of Internet and web technologies for advanced building management using remote control is still a great challenge for the RTD in the EU. Web-based building control systems are not yet standardised, but many companies now are making strong attempts to develop these technologies for universal usage, e.g. “The latest generation ‘Aspect’ technology” by Auto-Matrix opens up a new level of flexibility and capabilities for remote work with any Direct Digital Control (DDC) BMS by using mobile smart phones.

(MCC IV) Energy Management and Trading, including:

- Integrated Tools for Buildings Performance Monitoring, Diagnostics, and Predictive Management: We have identified a need to develop distributed systems based on agent technology. This technology would support the development of flexible IT-architectures for energy management and trading.
- Data Modelling: The interoperability amongst three fields is required - Construction, Energy Management and ICT. Commonly agreed data modelling methodologies are required.
- Advanced Decision Support: Novel decision support tools are required to support complex constraint patterns which are required to specify the diverse dependencies of local energy generators, storage devices and (sub-metered) end-user devices.
- It is necessary to extend the development of modern constraint-based preference models and optimisation algorithms that generate and support the configuration, adaptation and servicing of smart buildings, and the networks to manage them. It is including the development of specific languages and tools for the stakeholders to express their context-dependent (both absolute and relative) preferences to the building’s configuration and management systems. An interface should have to allow building users to specify their current perception of the environment, and should recommend actions available to the user. It is desirable these building management policies to be intuitive, self-learning and reporting, so that the system’s self-motivated actions will lead to improved building performance.

(MCC V) Integration Technologies, including:

- New System Roles: As new business models will appear, the privileges and constraints for different actors will need to be specified (in agreement with governance bodies).
- Business Work Flows: The development of new data exchange policies amongst different stakeholders was identified as a future R&D activity.
- There exists a huge business potential in development of robust, user driven decision support applications for BMS and energy management, providing energy calculations, simulation and

visualisation. These applications should provide users with easily understandable energy performance indicators, which will help consumers to make intelligence led decisions.

Integration of RTD results

One of the most significant challenges for the majority of research activities, which has a big influence on the process of physical implementation of RTD-results in practice, is the Management of Integration issue.

The management of integration is based on informational management, which has to allow all parties efficient communication and access to quality information sources. The availability of these conditions will support uninterrupted workflow and overall RTD results integration and knowledge flows.

Opportunities and stimulations for the integration of RTD-results could be determined in the following areas:

- Different scientific disciplines;
- Different stakeholders, e.g. domestic and business environment, leading to improvements of different technical and operational systems;
- Research and demonstration environments for future projects;
- Development of future, cross-sectoral strategies of further research activities

Cartography of European & International Research Initiatives as a Quantitative Gap Analysis of selected RTD

The strategic roadmap (presented in the next chapter) is a blueprint for Europe to develop a world-class portfolio of affordable, clean, efficient and low-emission energy technologies. The cartography of European and International Research initiatives helps towards the realisation of such a blueprint.

The cartography process of EU and International RTD's, as a part of overall Gap Analysis presented herein will allow to:

- Reach an understanding of the global picture of the current status of "ICT for building's EE" research domain;
- Gain the consensus about a set of RTD's results and further needs, as well as to define technologies and efforts required to satisfy those needs;
- Provide a mechanism to help forecast technology developments in the area ICT for energy efficient buildings;
- Develop a framework to plan and coordinate research activities by RTD's coordinating bodies.

Research projects were collected, analysed and properly categorised by the type of RTD developers as well as by the country/ies where these researches performed. All necessary statistic information has been extracted for further quantitative analysis.

As a first conclusion for cartography of European and International research we can represent the distribution of the currently performed (as well as recently finished) research activities per country of EU together with an overall number of these RTD performers.

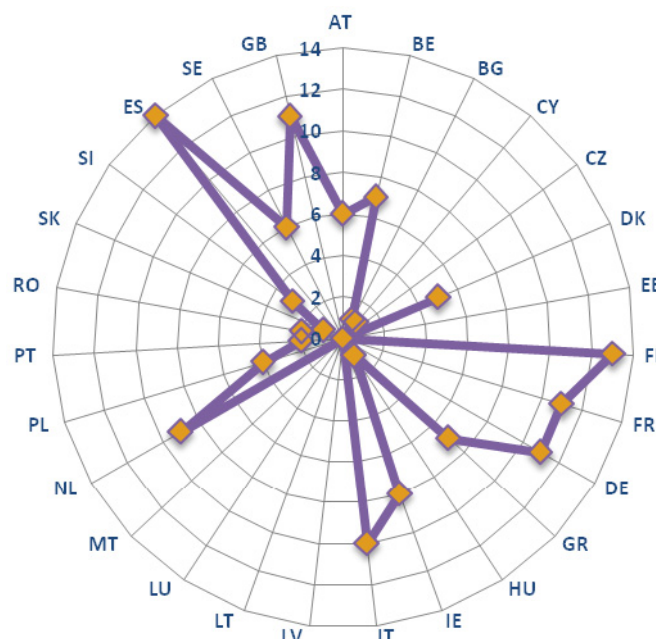


Figure 20: Distribution of selected RTD per country (Europe)

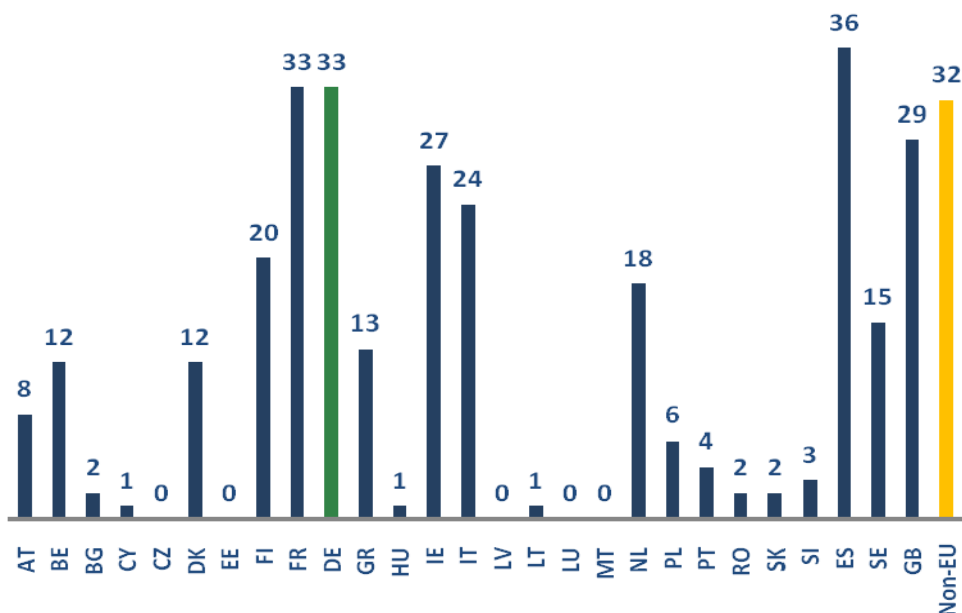


Figure 21: Number of all RTD participants per country

The un-proportional distribution of ICT for energy efficient buildings related RTD developers per country is evident from the figure above. There are very limited number (or even absence) of research performers in some countries (e.g. Latvia, Romania, Bulgaria) which contrasts with the large participation of some countries with better established research industries (e.g. Spain, France, Great Britain, and Finland).

The following figure represents the global picture of RTD participant’s percentage distribution per country of their location.

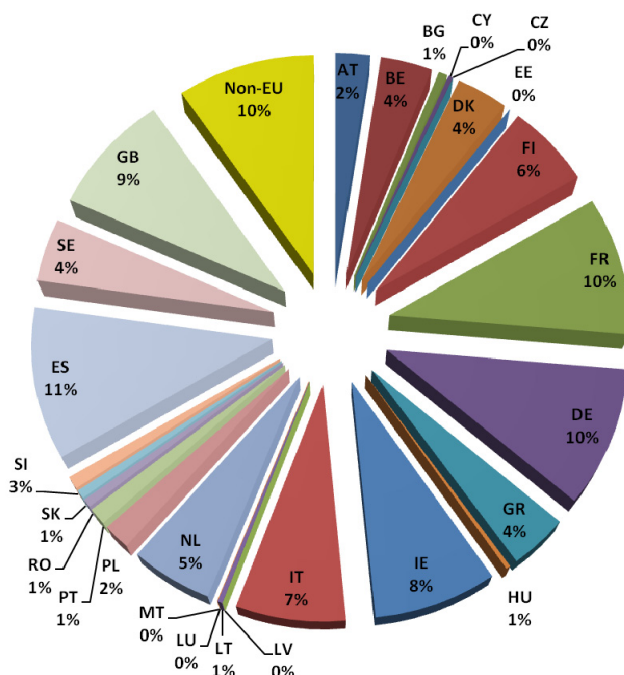


Figure 22: Percent distribution of all RTD participants per country

During further analysis of selected researching activities the distribution of the research participants (by the type of RTD developer – “Academic” or “Others”) per countries of their location was evaluated. The following figure presents the results of this analysis:

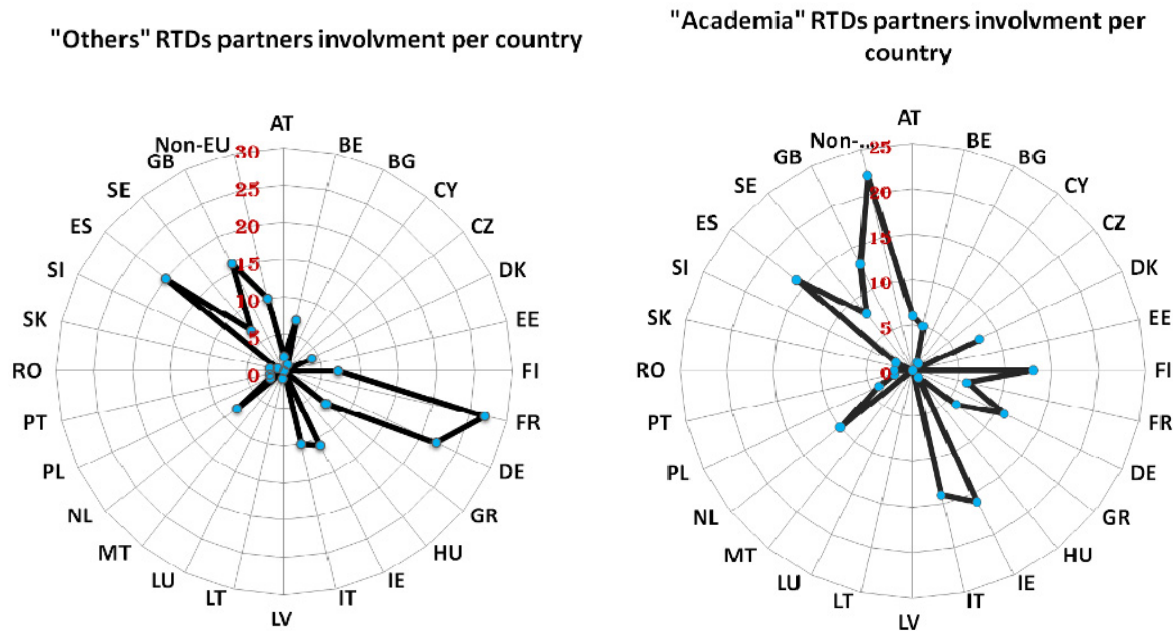


Figure 23: Distribution of RTD partners per country (non-EU included)

After the quantitative analysis of selected RTD and their participants on global level, it can be suggested that the involvement of industry partners into research activities is quite significant, in equal percentage parity with academics research developers.

In the near future a wider European research vision might be required, especially emphasizing on the latest recommendation from the Copenhagen Climate Conference which was held in December 2009.

Future research should be integrated and harmonised with demonstration activities. It would provide to society an overall understanding how ICT can be applied to a much wider range of circumstances in building energy management processes in all life-cycle stages. Furthermore, this would allow for effective and broad scale knowledge transfer from academia to industry.

Roadmap

Roadmap

Scope and Context

ICT contributions to the energy efficiency of buildings are mainly via a multitude of design tools, automation & control systems, decision support to various stakeholders throughout the whole life of buildings, etc. This topic is in the intersection of three disciplines: building/construction, ICT and energy. Some examples of relevant items for an integrative approach are listed in the below figure.

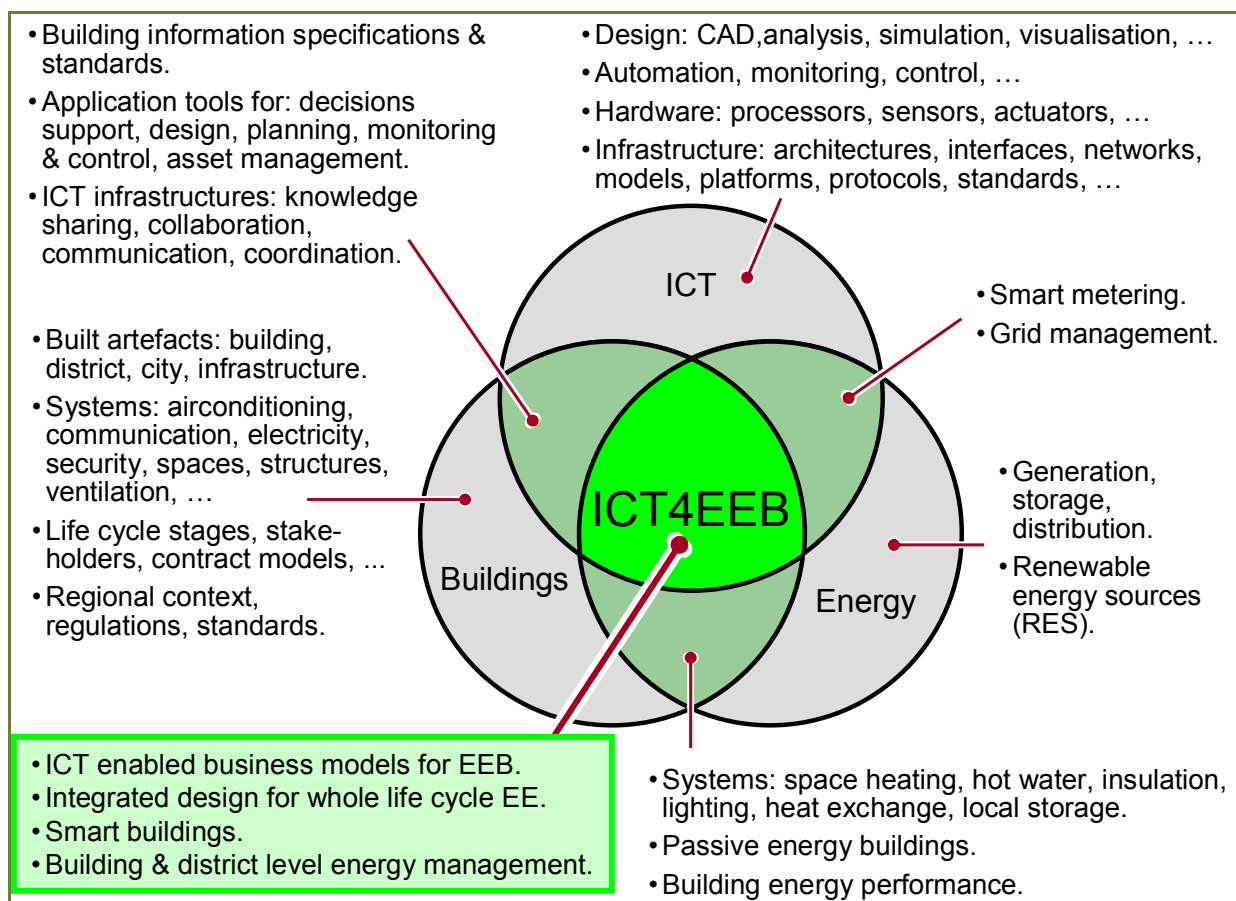


Figure 24: Scope of the ICT for energy efficient buildings vision

ICT Impacts on Energy Efficiency of Buildings

The relevance of ICT on the energy efficiency of buildings is mainly as follows:

- Short term: Assuring compliance to regulated minimum energy performance levels in design and renovation stages.
- Medium term: Decision support for life cycle cost/performance optimisation. Real time operation, control and user empowerment.
- Long term: Holistic optimisation of built environments considering: energy generation and usage of individual buildings, energy balancing between buildings within a district, responding to grid load and feeding excess energy into the grid. New business models driven by whole life time performance.

Structuring RTD Priorities

A common taxonomy has been defined in order to ensure broad coverage of the scope of the ICT4EEB domain, to harmonise work within the project and to present the project results in a consistent way. In this roadmap, the RTD topics are organised in the following categories:

I. EE design and production management

- Design: CAD, configuration management, visualisation of design solutions.
- Production management: contract & supply network management, procurement, logistics, on-site and off-site production management.
- Modelling: building & district modelling, ontologies, semantic mapping.
- Performance estimation: simulation, whole-life costing, life cycle assessment.

II. Intelligent control

- Automation & control: system concepts, intelligent HVAC, smart lighting, ICT for micro-generation & storage systems, predictive control.
- Monitoring: instrumentation: smart metering.
- Quality of service: improved diagnostics, secure communications.
- Wireless sensor networks: hardware, operating systems, network design.

III. User awareness and decision support

- Performance management: Understanding ICT impacts, performance specification, performance metrics, performance analysis and evaluation, conformance validation, commissioning, audits, labelling.
- Visualisation of energy use
- Behavioural change by real-time pricing.

IV. Energy management and trading

- Building and district energy management: building management systems, metering infrastructure, on-demand energy management and optimisation, load and distributed energy resources forecast algorithms, smart appliances.
- Smart grids: demand response capabilities, real-time self-assessment, load balancing techniques, energy network design and integration, secure, ubiquitous and low-latency communications.

V. Integration technologies

- Process integration: collaboration support, groupware tools, electronic conferencing, distributed systems, business work flows.
- System integration: plug & play, connections, service oriented architectures, integration and service platforms, cabling, gateways, middleware, development methods and tools.
- Interoperability & standards: BIM standardisation, simulation and interoperability, protocols for real time operation, energy trading protocols.
- Knowledge sharing: access to knowledge, knowledge management, knowledge repositories, knowledge mining and semantic search, long-term data archival and recovery.
- Virtualisation of the built environment.

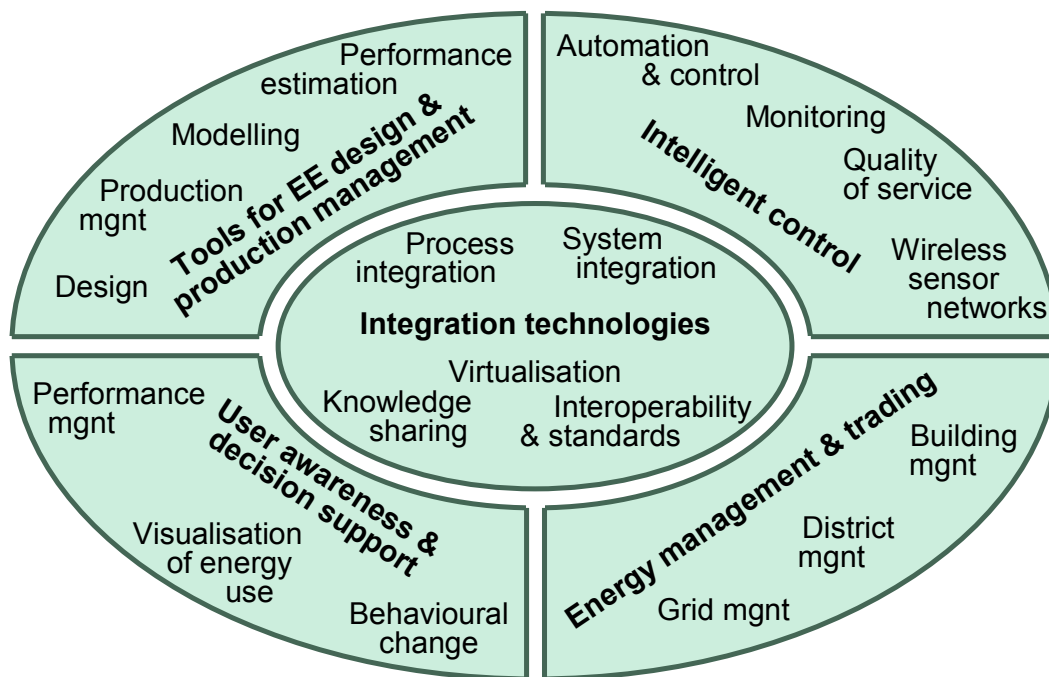


Figure 25: RTD priorities in the “ICT for energy efficient buildings” domain (ICT enablers)

Full exploitation of the opportunities offered by ICT for energy efficiency requires changes of the processes and contractual practices of the construction sector. The core is a transformation of focus from the initial construction cost to whole life performance i.e. value to owners, especially with regard to energy performance (*Error! Reference source not found.*). Although “Performance driven business models” are seen as the main drivers for energy efficient buildings, RTD on business models is regarded to be outside of the scope, which is concerned about the ICT enablers.

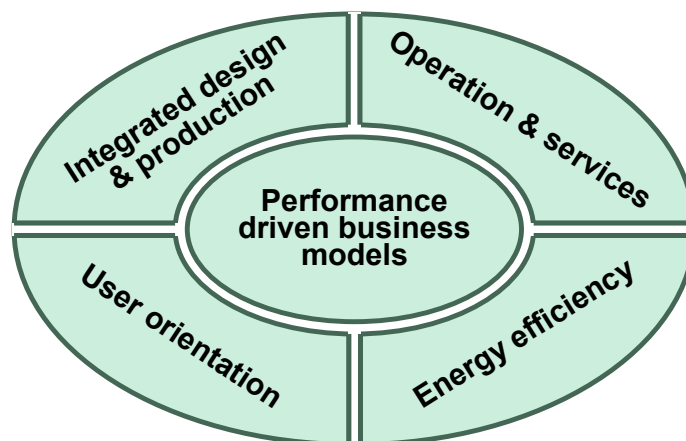


Figure 26: Industrial sector priorities (drivers for ICT use)

Table 2: Key RTD topics

Categories and subcategories		RTD topics		
Tools for EE design & production management	• Design	CAD; Various other analysis and design applications; Configuration management; Visualisation of design solutions.		
	• Production management	Contract and supply network management; Procurement; Logistics; On-site and off-site production management:		
	• Modelling	Building and district energy models; Ontologies; Semantic mapping.		
	• Performance estimation	Simulation; Whole-life costing; Life cycle assessment.		
Intelligent and integrated control	• Automation & control	System concepts; Intelligent HVAC; Smart lighting; ICT support for microgeneration and storage systems; Predictive control.		
	• Monitoring	Instrumentation; Smart metering.		
	• Quality of service	Improved diagnostics; Secure communications.		
	• Wireless sensor networks	Hardware; Operating systems; Network design.		
User awareness & decision support	• Performance management	Understanding ICT impacts; Performance specification; Performance metrics; Performance analysis and evaluation; Conformance validation; Commissioning; Audits; labelling.		
	• Behavioural change	Visualisation of energy use; Real time pricing.		
Energy management & trading: buildings, districts, grids	• Real-time response and predictive management	Embedded sensing, automation and control; Real-Time Self Assessment; Network planning; Condition and Performance-based maintenance:	Performance analysis and evaluation; Secure, ubiquitous communication	Decision support algorithms
	• Enhanced design and integration	Network planning; Plug and play scalable integration of micro-generation and storage		
	• Distributed generation and demand response	Demand response capabilities; Load balancing techniques;		
Integration technologies	• Process integration	Collaboration support; Groupware tools; Electronic conferencing; Distributed systems; Business work flows.		
	• System integration	Plug & play; Connections, Service oriented architectures; Integration and service platforms; Cabling; Gateways; Middleware; Development methods and tools.		
	• Interoperability & standards	BIM standardisation; Simulation and interoperability; Protocols for real time operation; Energy trading protocols.		
	• Knowledge sharing	Access to knowledge; Knowledge management; Knowledge repositories; Knowledge mining and semantic search; Long-term data archival and recovery.		
	• Virtualisation of built environment	Office optimisation; Virtualisation; Electronic conferencing; Virtual workplaces; Dematerialisation of physical processes.		

I. Energy Efficient Design & Production Management

Vision

Integration of BIM-CAD, dynamic energy simulation and visualisation: The planners (architects and engineers) are provided with appropriate means, such as simple energy estimation tools, so that the future building performance becomes obvious to them from the very beginning of design. The building service engineers are involved in an early stage, using energy simulation tools which are interoperable with the integrated BIM-CAD (Building Information Modelling) used by architects.

Information from energy validations based on local and/or European standards are visualized for decision making by stakeholders who are not necessarily energy experts. As the design evolves, more realistic energy analyses, using dynamic simulation methods, are made based on the increased granularity of the BIM. As a result, the building service equipment will be optimised, avoiding over- or under-dimensioning.

Virtual testing: The impacts on energy and emissions of new and improved building components (products), processes (e.g. building operation) and services can be tested in “Virtual Energy Lab” which is based on a building energy simulator.

Design for mass-customisation: Re-usable design solutions as parametric / configurable templates are available for adaptation into custom situations e.g. components, rooms/spaces, building services subsystems etc. ICT in this domain enables industrialised delivery of EE solutions for new and especially renovated buildings.

Integrated (distributed) engineering environment supports concurrent engineering between all stakeholders involved in the design and planning, and beyond - the whole subsequent life time of a building. It includes a suite of interoperable tools based on a common ontology and transparent services for data and model management.

Scenarios

By following a careful design process, it is possible to produce buildings that use substantially less energy without compromising occupant comfort or the building’s functionality. Whole-building design considers the energy-related impacts and interactions of all building components, including the building site; its envelope (walls, windows, doors, and roof); its heating, ventilation, and air-conditioning (HVAC) system; and its lighting, controls, and equipment. Low-energy building design is not about applying isolated technologies, it is an integrated whole-building process which complexity demands the expert integration of the several design stages. They need different design tools which may be common components and which have to be interoperable.

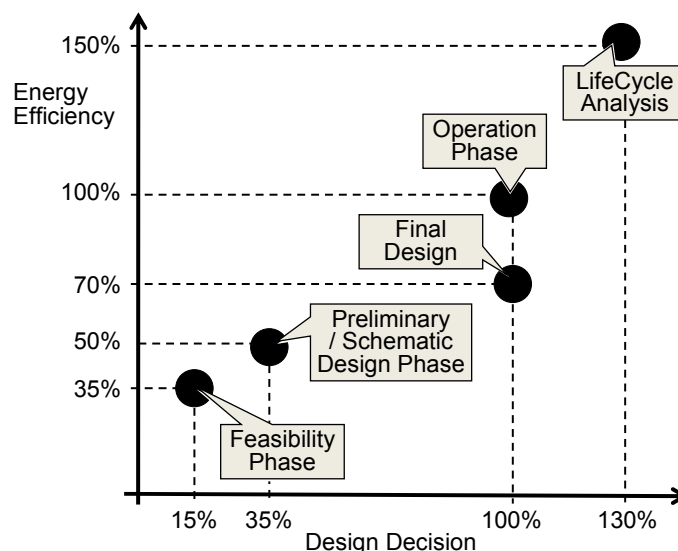


Figure 27: Achievable energy efficiency per design decision phase (estimates)

These design stages can be seen as the lifecycle of design:

Feasibility Phase / Conceptual Design: In this phase basic energy scenarios (i.e.: energy mix) are investigated and the classes of the energy subsystem (energy providing, heating, cooling, isolation, etc. systems) are drafted and determined.

Preliminary design/ Schematic Design: Building is modeled in climatic zones where a zone reflects the group of rooms with similar kind of energy behavior. In this phase the components of the basic subsystems are determined, which means, the class of windows, wall structure, boiler, ventilation, etc. and their locations are defined. It is also defined the room functions and equipment; quality performance of the systems; the energy balance is calculated in detail, the performance of building and systems are being verified and it is identify the sensitivity of energy performance- building simulation-system simulation-daylight simulation and the cost-benefit estimation is performed.

Final Design: Each room is a climatic zone, and rooms may be subdivided into several climatic zones or several rooms are united into one climatic zone. In this phase the product types of each component and their exact location and interaction are determined. This is a sophisticated engineering task, because a system is to be assembled from components coming from different suppliers, where standardization is not always given. The design integration which evaluates the influence of energy performance design solutions and the consequent update cost-benefit evaluation, operation prognostics which documents control strategies, metering and monitoring concepts. The design verification which includes the feasibility prove and the practicability and maintainability of technical installations.

Operation phase: During operation the actual building performance is compared with the designed performance. The system as given is tuned in the daily operation in order to improve delivery and efficiency.

Lifecycle Analysis: In this phase case studies are run to improve the operation of the system in the future concerning control and workflow and also to detect weakness or study the interoperation of new products, processes and services for improvement of the system which may accumulate in a renovation of the energy system or the whole building.

Key Research Topics

- Integrated engineering is a key to the definition of energy efficient buildings: integration of various tools to support a holistic process bringing together the views of different stakeholders to address the whole life of buildings.

User interfaces: filter methods for creating model views, navigation in time-dependent multidimensional information spaces, visualisation.

Improved theory and models of the energy behaviour of buildings, and the potential impacts of various ICT-based approaches on it. Validation and tuning of methods via comparison with monitored data.

Integration technologies: Other generic technologies serving the integration of many different types of application are addressed in section 2.5. They include e.g.: ICT support for collaborative design and planning in a range of engineering tasks over the building life cycle; interoperability and standards, and Knowledge sharing technologies supporting accumulation and re-use of design experiences and proven solutions.

- “Design for energy efficiency” tools (D4EE) covering a broad range of CAD and other applications for design and planning of buildings - both new and existing to be renovated - and the urban infrastructure; configuration management for re-using and adapting proven solutions; visualisation of design alternatives and solutions. Reducing need for many special purpose tools via embedded EE functionality in already used design tools. Easy to use, simple EE tools for early stages of design.
- Production management covering: contracts & supply network management; procurement; logistics; on-site and off-site production management.
- Modelling: Building modelling (BIM), district modelling, model granularities, ontologies for eeBIM, semantic mapping; Standardized Semantic Data Models
- Performance estimation covering various methods that are used at design stage to estimate the performance of the building for decision making and contracts e.g. simulation, whole-life costing and life cycle impact assessment. Research topics include: Definition of performance indicators and methods to assess them using available information from various ICT systems; Validation / certification of SW tools; Virtual testing; Integration of BIM-CAD and simulation; Simplified EE assessment and optimisation; Integrated environment for EE assessment; EE knowledge base. Tools to estimate EE performance in a quantified and verifiable way.

Roadmap

The following figure illustrates the roadmap for energy efficient design and production management. It covers the current state-of-the-art and research priorities in the short, medium, and long term.

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.	Enhancement 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 catalogues 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-real-time 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 28: Roadmap for energy efficient integrated design and production

Drivers

- Increasing regulatory requirements and client/user expectations regarding EE due to increasing energy costs.
- Emerging open construction market at EU level, calling for more industrialised, systemic and “branded” solutions.

Barriers

- Current contractual practice focuses on initial investment instead of whole life cost. Therefore the incentives are lacking for many stakeholders to take necessary actions for EE.
- Specialised ICT tools, extra efforts and special competences are needed for EE design, analysis & planning.
- Lack of experts and labour for extensive EE renovation of the European building stock.

Impacts

Opportunities to software developers to provide new EE design/planning tools, interfaces to other tools, and to enhance existing tools with embedded EE features.

II. Intelligent and Integrated Control

Vision

The future buildings, along with their components, equipments, and their environment will communicate and be able to provide information on their status ubiquitously. This real-time available information will be interoperable via common protocols for holistic automation & control. The whole building will be supervised by intelligent systems, able to combine information from all connected devices, from the Internet or from energy service providers in order to efficiently control HVAC (heating & cooling), lighting, and hot water systems along with energy production, storage and consumption devices inside the building, taking into account the users' needs and wishes.

Scenarios

a) Smart Box

It has been a windy night and wind farms were at maximum power. The electricity price level, communicated via the smart meter to the Energy box, was at 10% of the average daytime level. The Energy box decided to stock energy as cold in the freezer. When prices rose again, at about 5am, temperature in the freezer has reached -40°C. The energy box stopped the freezer. During the whole following day, and without any consumption of electricity at relatively high daytime level prices, the temperature of the freezer stayed below the value of -18°C.

b) Smart Office*

Tom stops by his office in a commercial building one Saturday evening. The proximity sensor reads Tom's smart card as he nears the front door. A security system verifies that Tom is indeed welcome, and unlocks the office door. The security system monitors Tom's entrance, making sure only one person enters, and automatically secures the door behind him. The building's air conditioning system is notified that Tom is on his way and begins to adjust his workspace to personalized settings. After several hours work, the building senses Tom's departure and returns to unoccupied settings. Intelligent sensors resume their watch as the security system is automatically rearmed.

c) Smart shutter^o

Mr. Smith has bought a motorised rolling shutter and fixed it over a window on the outside south wall of his house. The shutter is immediately automatically identified and authenticated on the network.

The central controlling "assistant or manager" is now aware of the existence of this new smart shutter and updates its control algorithms integrating this new actuator.

- In summer, when air conditioning might be necessary
 - The shutter is rolled down when local weather forecast indicates "sun shines". However, when occupancy sensors indicate the presence of a habitant, the corresponding energy saving from air conditioning is compared to the additional lighting consumption.
 - As soon as the local weather forecast indicates "rain or clouds", the shutter is rolled up.

* See: Smart Buildings, www.automatedbuildings.com/news/jan06/articles/labela/labela.htm

^o See: ZARLI, Alain. Towards an ICT infrastructure for Energy Positive Neighbourhood. European Large Scale Actions (ELSA): Thematic Working Group on ICT for Energy Efficiency. Brussels, 8th of October 2009.

- In winter, when heating might be necessary
 - The shutter is kept rolled up when local weather forecast indicates “sun shines”
 - The shutter is rolled down as soon as lighting becomes necessary in order to increase isolation of the windows

Until now, no human parameterisation has been necessary. If however, the adapted shutter strategy is not well accepted, the touch screen interface of the shutter allows modifying its behaviour, according to the wishes of the current habitants.

Key Research Topics

Automation and control consisting in methodologies, procedures and ICT systems that are able to manage (through actuators and embedded systems) all energy production and usage in a building, according to information received from inside the building (user interfaces, sensors, appliances, energy devices – production, storage, consumption) and outside (Internet, energy providers – ESCOs, district energy systems, weather, etc.) in order to ensure comfort, while optimizing the energy consumption of the building.

Monitoring relying on the instrumentation of the building with smart meters, other sensors, actuators, micro-chips, micro- and nano-embedded systems that allow collecting, filtering and producing information locally. This huge amount of distributed information is consolidated by a global monitoring system, in liaison with the Building Management System.

Quality of service covering issues such as improved diagnosis (allowing the monitoring and control system to auto-detect failures in the connected devices) and secure communications (ensuring full integrity of all data exchanges between applications).

Wireless sensors networks enabling all energy (consumption, production and storage) systems and conditions measurement devices to communicate. Wireless networks are particularly necessary for existing buildings where redeployment of cables is impossible.

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.

Drivers	Dynamic electricity prices, local production of electricity and storage	Increasing energy prices	Regulations and standards for energy efficiency of buildings
Barriers	ROI has still to be proven for users	Insufficient Interoperability	End-user acceptance
Impacts	Increasing demand for integrated BMS	Opportunities thanks to interoperability standard	“MS Home” (Energy Plus for everybody)

State of the Art	Short term	Medium term	Long term	Vision
<p>Quality of service: Some self-diagnosis systems exist in the HVAC and lighting domains. Some sensors can also monitor their own functioning, and communication protocols also include error detection in the data frame. For communication protocols, many open or proprietary de facto standards co-exist with different properties.</p>	<p>Enable diagnosis of EE-related building components (both “passive” ones like windows and active systems) has to be developed. Develop transmission protocols that satisfy specific ICT4EEB requirements (in terms of reliability, security, privacy...).</p>	<p>Generalize diagnosis of EE-related building components through the embedding of sensors in the components. Develop self-diagnosis abilities of sensors and integrate them in the sensors themselves. Develop a common shared standard of ICT4EEB-oriented communication protocol.</p>	<p>Develop BMS that will be fully auto-controlled and auto-monitored, discovering their own malfunctions. Achieve WSN that will be autonomous in their energy supply.</p>	<p>The future buildings, along with their components, equipments, and their environment will communicate and be able to provide information on their status ubiquitously. This real-time available information will be interoperable via common protocols for holistic automation & control. The whole building will be supervised by intelligent systems, able to combine information from all connected devices, from the Internet or from energy service providers in order to efficiently control HVAC (heating & cooling), lighting, and hot water systems along with energy</p>
<p>Monitoring: Existing Smart Meters enable real-time electricity consumption reporting and visualization as well as bidirectional communication with Smart Grids. All needed sensors, with the required sensitivity and accuracy, are not available at reasonable cost for a large scale deployment.</p>	<p>Develop new kinds of sensors when necessary, and decrease costs of manufacturing. Develop Smart Meters able to measure, record and visualize all kinds of energy consumption.</p>	<p>Make Smart Meters interoperate for the build-up of Smart Meter networks at district level. Embed more intelligence in sensors in order to perform a first level data analysis locally.</p>	<p>Tightly and securely integrate Smart Grids and Smart Buildings through Smart Meters, allowing the Smart Grid intelligence to directly control home appliances. Extend and distribute embedded intelligence to manage EE issues locally.</p>	

<p>Wireless sensor networks: Some “Plug & Play” sensors already exist, whose features can be automatically taken into account by WSN-based BMS to optimize control of the related actuators.</p>	<p>Improve sensors in terms of reliability, sensitivity, maintenance, testing and remote diagnosis, and communication abilities. Reduce energy consumption of WSN. Identify possible negative side-effects associated to WSN.</p>	<p>Define standardized roles and services for sensors and actuators to allow plug-and-play of new devices and self-(re)configuration of sensor networks. Allow WSN to support change of topology for network optimization. Develop powerful embedded OS that can provide more real-time functionalities.</p>	<p>Achieve completely autonomous sensors in terms of energy supply thanks to advanced energy harvesting technologies. Integrate several functions (light, temperature, air quality...) in a given sensor to reduce the number of necessary sensors. Integrate autonomous sensors in building components (windows, walls...) from the beginning of the construction process.</p>	<p>production, storage and consumption devices inside the building, taking into account the users' needs and wishes.</p>
<p>Automation & control: Existing automation and control algorithms are most often restricted to sub-systems (heating, light, ventilation, μ-generation...), independent from each other, and hard-coded in the devices with little possibility to update or modify them by a centralized control instance.</p>	<p>Develop holistic control strategies that integrate all building dimensions, and develop a common conceptual framework for interoperability with the definition of a relevant set of services for sensors/actuators. Take user activities and building usage into account. Implement predictive control by considering weather forecast. Address all BMS components for predictive maintenance.</p>	<p>Design new holistic control strategies by simulation. Integrate simulation tools in BMS to optimize control strategy in real-time.</p>	<p>Introduce self-learning features in control algorithms to adapt to the user’s preferences, the building age, and the possible change in the building environment. Allow control algorithms to suggest changes in the WSN (need of new sensors, disabling of existing ones...).</p>	

Figure 29: Roadmap for intelligent and integrated control

Drivers

a) Market segment of residential customers

⇒ Dynamic electricity prices

Through the growing implementation of Smart Meters and the rising of Smart Grid technologies, dynamic electricity prices, changing for example every 15 minutes, will soon become reality. The huge saving potentials can be easily understood.

Therefore, each house will install its control system that communicates

- On the one hand with the Smart Meter, to get the current electricity price and the forecasted prices for the hours to come
- And on the other hand with the fridge and the freezer, the washing machine and the dish washer, the electrical heating, ...

This is of course not really a pure scenario but this kind of system will be an embryo

- Of a Building Management System (BMS) requiring control algorithms
- Of a communication infrastructure between a central instance of intelligence and devices that are distributed inside the building

And will make people understand the potential of ICT4EEB.

⇒ Increase of locally generated electricity, corresponding storage devices and e-mobility requiring local charging station

Closely linked to dynamic electricity prices, the growing importance of locally generated electricity (e.g. PV systems), and eventually of corresponding storage devices, and e-mobility requiring local charging station will increase the need for a BMS controlling and optimizing the electricity flow.

⇒ New regulations and standards for energy efficiency of buildings

New regulations and standards, at European and national levels, for energy efficiency of buildings are as well a natural driver for ICT4EEB. As an example, we can quote the Building Energy Performance Directive, and the recently launched Energy Efficiency in Buildings and Eco-Innovation initiatives as well as the Lead Market Initiative on Sustainable Construction.

b) Market segment of professional customers

For the professional segment, where BMS are already in place, the situation is somehow simpler. In this segment, we will have a more continuous evolution towards more and more sophisticated BMS driven by

- Increasing energy prices
- Increasing technological possibilities allowing optimized and integrated BMS
- Potentially stricter regulation concerning energy consumption and GHG emissions
- Rising of the Smart Grid and dynamic electricity prices, local production of electricity and corresponding storage devices.

Barriers

a) Missing quantitative proof of added value / of ROI

It is very difficult to know a priori by which degree IIC will diminish the energy bill. This is currently one of the main barriers for IIC.

It is thus one of the most important tasks for the ICT4EEB R&D community

- To develop commonly shared and accepted simulation tools enabling to prove in an undeniable manner the added value / the ROI of IIC
- To perform field tests, thanks to pilot houses for example.

b) Insufficient Interoperability

Insufficient interoperability prevents

- Sub-systems (e.g. HVAC, lighting , security, etc.) to collaborate
- Systems to be flexible enough to cover the whole lifespan of a building.

Commonly elaborated and shared standards, for example for data transmission protocols between concerned devices, will improve the situation. These standards must also take into account maintenance handling and QoS aspects.

c) Social barriers

Use of IIC will only be accepted if the user keeps the impression to remain master of what happens. Each system must thus allow manual control and this one must always have priority.

User acceptance also requires that the technology has to be hidden behind well designed user interfaces that can implement multi-modal interactions with the system.

d) Regulation barriers

Absence of European standards is a further barrier for IIC use.

A European label for EEB for example would certainly help to push ICT4EEB. Such a label would be a complement to the US label LEED, the UK label BREEAM, and the German national label of the DGNB. Such a label must include formal guarantees that the performance of the system will remained unchanged for many years: reliability of components, QoS, quality labels, maintenance contracts with clearly defined liabilities, are some of the issues that have to be covered.

Impacts

a) An increasing demand for integrated Building Management solutions

The need for optimized Building Energy Management solutions

- Having a holistic approach combining HVAC, lighting, storage control, ...
 - Integrating all coming technological progresses in WSN
- will increase pressure on BMS suppliers to offer integrated solutions.

b) New business opportunities thanks to interoperability standards

Interoperability standards will create an opportunity for new entrants that might develop interoperable modules of BMS (only the control part, only the predictive maintenance part...). Existing BMS actors might therefore evolve towards the role of a system integrator.

c) A struggle for market dominance in the Energy Box market

Given the importance of the Energy Boxes for the residential ICT4EEB market and given the fact that these boxes might be commercialized via Utility companies, smart partnering with the right Utility could be crucial for ICT companies.

d) A “MS Home” (EnergyPlus for everybody)

There will be a demand for software enabling a residential customer to simulate its house and estimate the impacts of a given ICT4EEB product on the market.

In a second step, each ICT4EEB product might even come with a kind of driver / add-on to be integrated in such a “MS Home” enabling the house owner to simulate the benefits of this given ICT4EEB product for his specific building, before buying the product.

III. User Awareness and Decision Support

Vision

It is advocated that ICT must support understanding, capturing and formalising customer/client anticipations into requirements, conveying them to all stakeholders and validating compliance of ICT-based solutions with these requirements. Standardised methods and indicators are available for assessing and benchmarking the energy performance of buildings, systems and components. Performance audits, labelling and continuous commissioning are supported by recorded data of real time performance.

In terms of user awareness, it is anticipated that intuitive feedback will be given to users and operators on real time energy consumption and pricing, enabling them to optimise the control of the building and its usage– while at the same time being unobtrusive, and attuned to the user's available attention, taking into account both his/her activity and the urgency of the information that is notified to him/her. Overall, the concept of “user-friendly” environment has to be reinforced, i.e. easy to use (input) and easy to understand (output). New multimodal context-aware interfaces and devices will make the in-house network as simple to use as possible, thanks to a right combination of intelligent and interoperable services, relying on new techniques of man-machine interactions (ambient intelligence, augmented/dual reality, tangible interfaces, robots,...). These interfaces could be extended by means to share ambient energy-related information spaces thanks to personal advanced communication devices.

Scenarios

Key Research Topics

Performance management

Research on this topic will contribute to fine-tune building performance indicators (accuracy, comprehensiveness, ease of use), and create tools to give support to the end-user for performance improvement (decision support). The key identified RTD priorities are:

- Benchmarking tools to assess theoretical models towards data from real operations (*Short term*): Medium and large scale research projects should work to establish a new generation of performance management tools that integrate data from dynamic simulation models (DSM), and weigh them against the building real-time data monitoring. In particular, these DSM need to be dynamically linked and compared with the building to achieve conformance validation and continuous commissioning. Together with the usual real-time performance indicators, these new tools should provide decision support and advice for energy efficiency improvement according to optimal simulated reference patterns. More generally, these research actions will contribute to a seamless integration of tools and processes between building design and operational phases.
- Establishment of a performance track record database, including accurate building specifications (*Short term*): this research action is to establish a knowledge base that will record and centralize energy performance data of exemplary buildings. Each record will include comprehensive information about the building specifications and usage. This knowledge base will then serve as reference data to crosscheck results from building simulation tools, but also as a calibration / performance objective for future real constructions.
- Communities for sharing and ranking energy information (*Medium term*): Comparable to the recent growth of social networks, it is foreseen that energy performance data will become available through online communities, and therefore offer a potential for new added-value

services. Several medium to large research projects should be launched to prototype these new services enabled by the networking of energy information. Each service should be then trialled within a representative users' territory. Among all the envisaged scenarios, a first service could be a ranking platform of "energy consumers" with similar profiles. By comparing the performance data, the platform would provide advice for efficiency improvement as well as incentives (e.g. money savings perspective) to stimulate their implementation. By "energy consumers", it is implicitly meant that different scales can be investigated: end-users (occupants), buildings, districts, etc.

- Data security privacy (*Medium term*): this research topic closely relates to the previous one, since the online availability of personal energy information raises privacy issues. Dedicated research actions should address information ownership issues, screen attackers profiles and potential risks. It should then elaborate and propose appropriate strategies (technical, regulation, etc.) – or in case adapt strategies developed in other application fields - to prevent these risks, in collaboration with the service providers.
- Decision-support tools for energy trade between buildings/parts of buildings (*Medium term*): an in-depth analysis of energy consumptions and profiles should lead to the identification of energy trade strategies – therefore leading to solutions improving performance management at a macro-level (whole complex building, groups of buildings, energy-efficient districts, etc.). Research should focus on the identification of matching combinations of energy profiles (shifted energy needs and productions), allowing energy cooperation. Energy storage is a connected topic and therefore experts in this field could be associated to the research.

Strategies can be envisaged at the (whole) building level or district level, and therefore will provide feedback to building designers and local planners.

- Energy efficient buildings certification (*Long term*): long-term research is needed to create European labels for characterization (and further evaluation) of energy-efficient buildings. The labels should take into account the whole complexity of the building, and should consider its whole lifecycle. It should also take a comprehensive view on the energy consideration, i.e. integrating (and potentially differentiating information related to primary energy and final energy, integrating grey energy (to produce the energy) and consumed energy (power requirement), etc. Therefore the certification should be not only relying on the building equipment and design, but also on the verification of real-time performance on operation. Hence, ICT tools need to be developed to automate these future certification processes, in a flexible enough way so as to adapt then to country specificities.

Visualisation of energy use

Ongoing research projects on this topic need to be further continued, especially through multidisciplinary pilot projects (involving experts in mobility, user interfaces, sociologists, designers, etc.) so as to work on energy efficiency incentives and adequate energy visualisation presentations. The key identified RTD priorities are:

- User motivation and incentives (*Short term*): small scale research projects are needed for a classification of incentives & triggers per stakeholders in different contexts (e.g. residential, office, etc.). This research should be conducted through interviews of selected representatives and using panellist methods. The main expected outcome is the best content or package of information needed per stakeholder for energy-efficiency awareness and stimulation.
- Interfaces for energy display (*Short term*): medium and large scale research projects are needed to define the most appropriate way to present the energy information. One of the axis of the research is to fine-tune the metrics and units (e.g. kWh versus Euros) used in traditional interfaces (e.g. web based), as well as the information delivery process (e.g. information push).

A second aspect is to prototype innovative interfaces and display for energy visualisation; experts in design, ubiquitous yet unobtrusive interfaces, and mobility aspects should all together create the specifications for more intuitive and natural energy displays for buildings. This interface design should also take into account the natural trend of human beings to slowly pay less and less attention to displayed information.

- Energy awareness impact on user behaviour (*Short term*): pilot projects enabled by the latest energy visualisation techniques should contribute to assess the actual impact of energy visualisation on user behaviour – integrating as well the users’ feedback with respect to these visualisation techniques and interfaces. Using methodologies similar to clinical studies (e.g. placebo groups), the pilots will directly involve end-users sorted by profiles (age, activity, type of building, etc.). The investigation should help to determine the optimal strategies to obtain long-lasting eco-behaviours.
- Integrated energy visualisation tools (*Medium term*): cross-sectors research projects should be launched to create a new generation of integrated energy visualisation tools that encompass energy consumed in a comprehensive way (home, travel, office, etc...). These new tools would allow proactive (simulation) and reactive (real-time analysis) functionalities for a comprehensive evaluation of individual carbon footprints, showing the balance between the different consumption uses.
- Integrated information on grey energy (*Medium term*): medium to long term research is needed to establish “grey energy” indicators, taking into account not only the power requirement, but considering also energy production, transport, storage, as well as the disposal of products used. This research should lead to more accurate energy visualisations, and would of course impact the design choices and decisions for future building services.
- Training sessions on energy awareness (*Long term*): as a long term objective and based on the findings from the above mentioned research actions, training courses on energy awareness could be developed and proposed to all stakeholders in the field of construction. These training would include concrete good practices and guidelines for e.g. setting up eco-responsible campaigns in companies. To facilitate wide knowledge dissemination, all technologies such as eLearning, eCourses or learning games can be envisaged.
- Decision support for long-term “lifestyle” strategy (*Long term*): the long-term generation of user awareness tools could incorporate advanced simulation features to evaluate the interest of radical changes in lifestyle or way of working. Based on the accurate knowledge of current energy consumptions, these tools could for instance assess validity of telecommuting (teleworking) strategies, building relocation, new manufacturing processes, etc. Societal experts need to be associated to this research, as their insight on work & personal lifestyle major trends is essential.

Behavioural change by real-time pricing

New technologies for energy metering and local energy generation will considerably change the customer relationship with the energy providers. The implied change on regulation and business models offer new perspectives and need to be accompanied by new adapted ICT infrastructures. The key identified RTD priorities are:

- Tools for adjusting consumption to real-time pricing tariffs (*Short term*): it is wise to use pricing as one of the main incentives for stimulating eco-behaviours. Based on the latest technologies for accurate and flexible energy metering and remote communication with the energy provider, short term research actions can be performed to improve the offer: decision support algorithms to advise the end-user to consume at the cheapest time, semi-automated

scheduling systems connected to heavy consuming appliances, simulation programs allowing the customer to select a best-fitting energy contract according to personal energy consumption history, etc. A right balance will have to be found between what will be possibly controlled in a fully automated (simulation-based) way, and what will be let to a human decision.

- Adaptive energy contracts (*Medium term*): from the energy provider point of view, medium-term research actions are possible to build a new generation of energy contracts for customers, with flexible and personalized tariffs. New models (and ICT tools implementing and managing those models) will be needed to adapt in a fair way the contract to the customer behaviour and eco-responsibility. These models should naturally include local generation and energy trading scenarios.
- Personal energy rationing strategies (*Long term*): in some critical situations, or when vital energy efficiency efforts are needed (to ensure for instance stability of the grid, and avoid energy blackout), energy rationing strategies (limited energy credits allocated per entity) can be fully justified. Long-term research should lead to new energy systems incorporating features for putting these strategies in place for a temporary period.

Roadmap

The following figure illustrates the roadmap for user awareness and decision support. It covers the current state-of-the-art and research priorities in the short, medium, and long term.

Drivers	Regulations, awareness, cost reduction	New business opportunities based on energy savings	Whole life performance of buildings
Barriers	Contractual practice based on initial investment cost	Lack of evidence to support investments into EE	
Impacts	Increased EE through user empowerment	EE and financial services	Life cycle optimised buildings. Users as active players in energy market.

State of the Art	Short term	Medium term	Long term	Vision
Management of performance requirements: Currently only basic and aggregated energy monitoring indicators, lack of decision support functionalities	<ul style="list-style-type: none"> Benchmarking tools to assess theoretical models towards data from real operations Establishment of a performance track record database, including accurate building specifications 	<ul style="list-style-type: none"> Communities for sharing and ranking energy information Data security privacy Decision-support tools for energy trade between buildings/parts of buildings 	<ul style="list-style-type: none"> Energy efficient buildings certification 	Energy efficiency of buildings will be ensured by established models, methods and tools for: understanding customer/client perceived values; capturing and formalising requirements; conveying the requirements to all stakeholders; assessing the estimated or actual performance and expressing it with verifiable performance indicators; communicating/visualising the performance for decision making by the involved stakeholders.
Visualisation of energy usage: Some emerging technologies but need for further experimentation to assess actual impact, and need for more research to fine-tune information presentation and content.	<ul style="list-style-type: none"> User motivation and incentives Interfaces for energy display Energy awareness impact on user behaviour 	<ul style="list-style-type: none"> Integrated energy visualisation tools Integrated information on grey energy 	<ul style="list-style-type: none"> Training sessions on energy awareness Decision support for long-term “lifestyle” strategy 	
Behavioural change by real-time pricing tariffs: Basic existing systems that can be easily improved thanks to facilitated communication between consumers and energy providers	<ul style="list-style-type: none"> Tools for adjusting consumption to real-time pricing tariffs 	<ul style="list-style-type: none"> Adaptive energy contracts 	<ul style="list-style-type: none"> Personal energy rationing strategies 	

Figure 30: Roadmap for user awareness and decision support

Drivers

The main drivers are the increasing will of more and more users to get aware of energy consumption and efficiency (and more globally about environment consideration), as well as typically for building owners) regulatory requirements and the shift towards performance based contracts. All these increase emphasis on whole life time performance of buildings.

In addition, an important point to keep in mind is the following: the lower the energy consumption will be, the bigger the impact of occupant behaviour and the more important the control of the building will turn into: a key point here is that occupants will need to be trained to understand they are a key component in the building and of any EE strategy.

Barriers

Barriers include: the traditional contractual practice with focus on the initial investment cost without considering energy performance; lacking financial mechanisms and business models to support investments in energy efficiency; unawareness and also lack of evidence of the actual impact of ICT solutions and other investments for energy efficiency. Overall, decision-making is not supported by adequate information, in a context of complex and difficult automation.

For a more user-oriented point of view, there is a clear need for occupancy feedback to user to enable behaviour modification towards sustainability and energy efficiency, including e.g. definition of user requirements and preferences, dynamic and personalized environmental controls, visualization of data associated with energy use – but all this with the incorporation of the human dimension in ICT, especially through solutions that are “accepted” by the user, e.g. with systems naturally interacting with the user (voice, avatar, ...), with systems having the capacity to learn and adapt themselves to the way of living or working, with dynamic adaptability to the user specificity (handicap, health, age,...), etc. – overall issues related to human activity and energy efficiency, and to the design of interfaces accordingly.

Impacts

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. This will create new business opportunities to utilities, financial services (e.g. ESCOs), and suppliers of software and devices (e.g. smart meters and energy awareness displays).

IV. Energy Management and Trading

Vision

Energy management in buildings will become more complex due to the integration of multiple renewable energy sources into the built environment, therefore tools for advanced supply-demand data management are required.

As energy management will have to consider generation and demand capacities, as well as storage capacities of energy networks, decision support tools are needed for managing the interaction between the different “components” of the energy network at building, district, and global grid level.

Energy management systems will become more complex, therefore enhanced design and integration tools are required. For instance, network planning tools shall be capable of integrating basic model data from other design tools using standardised interfaces and web services.

To deal with variability of supply capacity of renewable energy sources, technologies for load balancing, performance analysis and demand response are required. This implies that systems and components must be equipped with intelligent control features (e.g. energy systems allowing for multi-level control at “zone level”, “building level”, etc.)

Scenarios

a). Protocols, processes, equipments and software tools enabling a real-time interaction between the building (or group of buildings) and the energy provider(s):

One potential application scenario is in the residential sector. The availability of “DYI-kits” containing a certain set of inexpensive wireless sensors and meters, and one or two active network components would allow the self-installation of a network for “Building Performance Monitoring. The package might be completed by a pre-installed piece of software allowing the reading of sensed and metered data on a local PC. When connected to either a smart meter or a DSL-modem (via an Access Point) the user could initiate the transmittance of performance and consumption profiles to a “central performance management server” of the Energy Provider.

Let’s assume the DYI-kit is designed in a modular way the functionality might be expanded in a second step by installing (wirelessly control) actuators, such as magnetic valves.

This would support a “zone based control” of the home energy network. However, this would require the implementation of a control model. Therefore, we assume that the major components of the network can provide their “technical specification” plus the knowledge about their “neighbouring components” on request to a central control component using a standardised data exchange format/protocol. This means, the system provides a self-configuration support through its re-engineering functions.

b). Smart metering for grid energy management:

Smart Meters are the “focal point” of this scenario description since they “bridge” the gap between the “internal energy management” and the “(external) distribution network”.

Smart Meters might have the capability to communicate with a central control device “behind” the meter which collects and evaluates all sensed and metered performance and consumption data. Secondly, Smart Meters do provide information about available supply capacity and the related pricing. This information is communicated and evaluated by the “control device”. The control device can decide (a) to reduce consumption by turning off or “slowing down”

consumers (b) increase the consumption by increasing the performance of consumers or charging storage devices.

Finally, Smart Meters will be capable to collect “consumption profiles” from the active control component, evaluate these, and predict a “Demand Profile” This predicted demand profile is broadcasted to the network operator.

Key Research Topics

Real-time response and Predictive Management:

Since in case of extended renewable energy generation the capacity in energy-grids is will substantially more depend on weather conditions the capabilities for load-balancing must be extended. This can be achieved through improved capabilities to predict the demand/supply capacity and the capability to quickly adjust demand and (local) supply to the current generation capacity (real-time response). The following chapter describes the research challenges in this area:

Embedded sensing, automation and control: research should focus on:

- Wireless Hardware Platforms, since wireless sensors and actuators can be easier installed in existing buildings. Their application will lead to cost savings for wiring.
- Further research is required focusing on energy harvesting (to ensure “long term, maintenance free” energy supply). Packaging needs to be customised to the requirements of the construction sector to ensure easy, “aesthetic” installation and optimal signal propagation within buildings.
- Innovative firmware needs to be developed to ensure “energy-optimal” operation of wireless sensors, meters and actuators leading to minimised maintenance costs.

Secure, ubiquitous communications: research should focus on:

- Communications protocols must ensure that sensed and metered data can be managed in a secure way. It should be impossible to analyse behavioural patterns of individual tenants or building users.
- Further research is required to improve the “self-adaptability” of networks. The requirement for network management should be minimised. Meshed network topologies are recommended.
- Standardised data exchange protocols are required to ensure market liberalisation and prohibit the dependency on specific vendor protocols.
- Research is required to optimise network traffic by introducing a clear separation of network traffic on the appropriate systems level (e.g. on apartment, building, or district grid level).
- Decision Support Algorithms: research in this area deliver the right level of software support for the development of decentralised metering and control;
- Real Time Self Assessment: developing the availability of consumption data on “item level”, allowing energy consumption overview in real-time;
- Condition and Performance-based maintenance: identification of the most efficient maintenance strategies and business processes models for it based on the real-time and stored data from BMS;

Enhanced Design and Integration:

These researches suppose to develop simplified interconnection standards, two-way power flow capabilities and more effective load balancing techniques to allow distributed generation and energy storage to be incorporated seamlessly into the transmission and distribution network, i.e.:

- Network Planning: projects stimulating “Knowledge Transfer” amongst the “Energy Sector” and the “Construction Sector” to enable representatives from both sectors to better understand the “advanced requirements” for interface design which will impact the overall network planning;
- Plug and Play scalable integration of micro-generation and storage: research focused on the development of dedicated storage capacities to optimise the functionality of single systems (e.g. the development of seasonal storages for solar heating), as well as directed to develop an integrated management of storage capacities in buildings.

Distributed Generation and Demand Response:

This sub-category have to contain those RTDs working on development and implementation of more effective energy load-balancing techniques, energy network performance analysis and evaluation, identification and improvement of the energy demand response capabilities, efficient stipulation of the low-latency communications.

- Demand Response Capabilities: development of integrated control for local energy generation and demand in combination with intelligent control of energy storage capacities to establish additional “demand response capabilities” on “local” level;
- Low-latency communications: research would provide communication between the generation devices, the control systems, the “consumers” and potential storage devices for efficient control over distributed energy;
- Load Balancing Techniques: So far, energy was required to operate buildings. Past and recent research has focused on the integration of additional, single renewable energy sources into the buildings’ energy system. Some work has been done to develop advanced control devices for photovoltaic systems;
- Performance Analysis and Evaluation: research focus on the adaptation of methodologies for multi-dimensional analysis and evaluation of the needs for the energy in buildings; energy performance data analysis (e.g. long-term measurement, geographical influence, seasonal influence, etc.).

Roadmap

The following figure illustrates the roadmap for energy management & trading. It covers the current state-of-the-art and research priorities in the short, medium, and long term.

Drivers	European and National Legislation	Holistic, integrated business models for Energy Management and Trading How to exploit energy data?	Requirement to reduce the Carbon Footprint of the Built Environment.
	Increasing availability of (renewable) energy sources	What value-added services are required from customers?	
Barriers	Privacy Who owns Energy Data? Where and how to manage energy data?	Restricted, non-standardised data-exchange protocols How to exchange energy data? What is the commercial value of Energy Data?	User Qualification What is the impact of my activities? What “upgrades”/actions create the most sustainable impact?
Impacts	Diversification for ICT-stakeholders:	Strengthening the Competitive Advantage of stakeholders from the Construction and the ICT-sector(s)	Reduction of Energy Consumption in Buildings Contribution towards the European Objective “20:20:20”

State of the Art	Short term	Medium term		Long term	Vision	
Building energy management:	Embedded Sensing, automation & control Real-Time Self Assessment	Decision Support Algorithms Performance Analysis and Evaluation	Secure, ubiquitous communication	Network Planning	To support the integrated and secure operation of “cascading” energy generation, storage and consumption capacities in the best interest of all energy consumers, the environment and the overall society – using a business model that enables the beneficial operation of integrated energy infrastructure systems.	
District energy management:	Integrated System Platforms Low-latency communications					Plug and Play scalable integration of micro-generation & storage
Grid management:	Demand Response Capabilities:					Load Balancing Techniques

Figure 30: Roadmap for energy management and trading

Drivers

The major driver for R&D activities focusing on Energy Management and Trading is the requirement to reduce the Carbon Footprint of the Built Environment. This general requirement is underpinned by European and National Legislation, such as the European Energy Services Directive (amongst many others). Furthermore, National legislation or National Programmes request or stimulate the introduction of smart meter technology. Finally, these activities are complemented by National programmes to stimulate the installation of renewable energy systems and passive and active building technologies contributing to energy savings.

Conclusion: The first major driver for R&D in Energy Management and Trading is the increasing number of available (renewable) energy sources and the related National, European, and International legislation.

The second major driver for R&D activities focusing on Energy Management and Trading is the introduction of new, holistic, integrated business models for Energy Management and Trading.

(1) PPP-type contracts: In case of Public-Private-Partnerships the “risk of ownership” is transferred from the user of the building to the PPP-members. Energy costs are a substantial part of the operational costs. The ability to decide about the efficient usage of an “Energy Mix” from renewable sources (associated to the building) and other external sources will substantially influence the operational costs and will thus become a “key success factor”.

(2) ESCO: In case of Energy Service Companies the underlying business model is based on the assumption that the “Total Energy Service Provider” shares the savings generated from the optimised Energy Management and related Value Added Services (e.g. performance based maintenance of systems and components) with the owner or tenant of the building. The capability to participate in flexible “trading” with multiple energy providers (gas, electricity, others) is an essential enabler for the holistic optimisation of selling, buying or storing energy. Furthermore, the capability to precisely monitor and analyse the building performance and the related energy consumption is a pre-requisite for offering further “Value-Added Services” to ESCO customers.

Barriers

Privacy: Advanced Energy Management and Trading is based on the assumption that consumption and performance data are compiled, stored and analysed in a fine granularity. The availability of detailed data tracking the usage and performance of heating, lighting and appliances inherits the risk that this data can be misused by third parties to analyse the “user behaviour” in an inappropriate way, interfering with the privacy of building tenants.

Restricted, non-standardised data-exchange protocols: It is essential to introduce standardised formats and protocols for the exchange of data describing the Energy-Demand and Supply Profile of tenants. Non-standardised, provider-specific formats might negatively impact market competition and enforce customers to stay with certain, dedicated providers.

User Qualification: It is essential that platforms for Energy Management and Trading can be easily installed and operated, even by users with limited expertise and skills.

Impacts

Diversification for ICT-stakeholders: The capability of stakeholders from the ICT sector to offer holistic, integrated service platforms to offer value-added services for Energy Management and Trading along the whole value chain from the development and manufacturing of embedded sensing, automation and control hardware-software system, complemented by domain specific

software tools focusing on decision support, assessment, performance analysis, intelligent control, maintenance management, network design and operation allows the ICT-stakeholders to address a broader market, to bundle services, to use synergy effect and to ensure efficiency gains.

Strengthening the Competitive Advantage of stakeholders from the Construction sector: The capability to provide an “Energy Service Platform” will enable stakeholders to expand their business towards Total Facilities Management and Life-cycle Oriented Building Management. Stakeholders will benefit from their (already existing) engineering expertise and their technical skill sets and complement their portfolio of technical-oriented service towards management and business-oriented services.

V. Integration Technologies

Vision

EEB is managed in a holistic way through the seamless integration of the ICT tools that are used in the different stages of the building life cycle (definition, realization and usage), both off-line and real-time processes, in such a way that the building becomes an active component in the energy networks. The integration of ICT tools is also complemented by the integration and cooperation among the multiple stakeholders that take part in the building life cycle, in such a way that better decision making processes are achieved by the participation of all relevant actors and taking advantage of the experiences in existing buildings. The increasing energy demand in buildings due to the massive adoption of ICT systems will be mitigated by the adoption of strategies for virtualisation of built environment.

Scenarios

a). Websites used to gather and disseminate energy-efficiency "good practices"

Users are in a position to type a question and retrieve relevant answers on the energy performance of similar types of buildings as theirs. Through this, they can make informed decisions on how to improve the energy performance of their buildings. Based on their decisions and corresponding actions, the knowledge/experience gained is transferred to relevant websites for incorporation in new/updated good practices. Furthermore, websites are considered to be able to use intelligent semantic search and knowledge mining to extract knowledge from other industrial disciplines (e.g. manufacturing, aerospace, etc.) to propose possible solutions to problems that have not yet been reported/documentated in the building industry.

b). Information standards: BIM for energy information modelling data

You are discussing with the architect the design of your new home. You suggest him increasing the size of bedrooms and living room windows and using more energy efficient glasses. He makes the changes through his CAD tool (size, material and unitary costs) and updates the corresponding BIM with the new windows. These changes automatically launch the energy simulation tool, which reads the updated BIM and in few seconds update it with the results of the energy simulation. The updating of the BIM with the energy simulation results automatically launches the cost analysis tool and it provides you in few seconds information about the new building realization cost and energy costs during building life cycle. You make a final decision about the change with a detailed knowledge about its impact in the energy consumption of the building and its cost.

c). Communication standards: network protocols for energy data exchange

The BEMs that you have installed in your building provide you detailed information about the use of energy (lighting, computers, HVAC,...). This information is automatically read and analyzed by your facility management tool and detect that the energy consumption for HVAC is increasing. This data are compared with the data of your neighbourhood that are offered by the ESCO and it is observed they have not been increased in this period. You ask for a review of the system and it is detected that the boiler is not working properly. The boiler is repaired and the energy consumption returns to the expected values.

Key Research Topics

According with the increasing complexity of the buildings and need of increasing their energy performances, day by day there will be higher demand of ICT tools that make possible:

- more agile collaboration among the multiple stakeholders that interact through the building life cycle.
- the interoperability among the increasing number of ICT tools and energy management systems that are used during building life cycle for the own building design and operation (architects, promoters, users...)and its relation with external stakeholders (utilities, local authorities...).
- sharing the knowledge that is generated during buildings life cycle.
- reducing the energy demand of the ICT systems.

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

- **Process integration**, which addresses RTD needs in relation with collaboration support tools and business work flows.
- **System integration**: Plug & play; Connections; Service oriented architectures; Integration platforms+ value added services; Cabling; Gateways; Middleware; Development methods and tools (Integrated design environments (IDE); HW simulation & testing environments; UML profiles; Data modelling methods).
- **Interoperability & standards**, which addresses RTD needs in relation with data models and real time (in-side and out-side building) communication protocols.
- **Knowledge sharing**: Access to knowledge; Knowledge management; Knowledge repositories (Contents; Personalisation / user profiling); Knowledge mining and semantic search; Long-term data archival and recovery.
- **Virtualisation of built environment**: Office optimisation; Server virtualisation technology.

Roadmap

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

Drivers	<ul style="list-style-type: none"> - Digitalization of building process and future generations - Social awareness about relevance of energy efficiency and evolution toward real-time energy cost - Integration of local generation in buildings
Barriers	<ul style="list-style-type: none"> - Fragmentation and “project oriented approach” of building sector and lack of knowledge about building life cycle energy costs - Complexity of dealing with existing buildings - Current energy price policies
Impacts	<ul style="list-style-type: none"> - Better knowledge about building life cycle energy performance and more affordable energy efficient buildings - Implementation of the SmartGrid concept. - New business opportunities for ICT, energy and building sectors - Higher sustainability with lesser consumption of resources (i.e. travel, energy, etc) via changes to the way we work

State of the Art	Short term	Medium term	Long term	Vision
Process integration: Files are the main integration mechanism and email the communication tool	Information server based workflows	Friendlier interaction with the information systems	Intelligent workflows	EEB is managed in a holistic way through the seamless integration of the definition, realization and usage stages oriented design and operation tools and the collaboration of all the stakeholders in order to achieve the maximum energy efficiency in the building life cycle and taking advantage of the experience in previous buildings.
System integration: A wide variety of different technologies, from different vendors and companies, are coexisting	Definition of the gateway installed in each buildings and SOA based Integration Service Platform (ISP)	Making more efficient and friendly ISP and extending it neighbourhood level	Creating a common European vocabulary and new development methods and tools	
Interoperability & standards: Many non interoperable and partial standards	Definition of a common BIM for building life cycle energy efficiency	Unified open communication standard for monitoring and basic control operation	Uncertainty management and integration with standards from other domains	
Knowledge sharing: Even when knowledge exists, it is not discovered because is scattered in different non-compatible media and formats..	Continuous learning; community forums for discussion; Intelligent digital catalogues of building products/services containing parametric information.	Easy access to knowledge about energy efficiency in building, which is modelled according to standards; User awareness tools (syndication).	Template solutions based on good practices; Ubiquitous and context-based access to interorganisational knowledge platforms.	

Virtualisation:	Definition of the “Office of the Future”; Application Virtualisation; Human controlled avatar in 3D virtual meetings	Virtual Office Space; Virtualisation incorporating Cloud computing and Software-as-a-Service (SaaS); Head-Up Displays for virtual reality meetings	Virtual Personalised Desk and Energy Harvesting for Office of the Future; Real-time and self-predictive/adaptive virtualisation	
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Figure 32: Roadmap for integration technologies

Drivers

The main driver that pushes the previous technological changes is the digitalization of building process and future generations. Currently, computers and Internet are present any office and building site and also in many homes. At the same time, the new generation of professionals has been playing and learning with computers since their youth. Consequently, the basic infrastructures and skills are already available or will be very soon.

Also the increasing social awareness about the problem of the Climatic Change and its relation with the building's energy consumption and the expected evolution toward real-time energy cost will increase the demand of ICT solutions to increase the energy efficiency of new and existing buildings.

In parallel, the evolution toward the SmartGrid concept will require changing the current static building's role as energy consumer to a dynamic one, as energy "prosumer" (producer–consumer).

Barriers

The main barrier to the adoption of the new technological developments by the building sector is its fragmentation and "project oriented approach". A lot of stakeholders take part in the building life cycle, many of them SMEs or even micro-SMEs, and usually, no one leads the overall process. Also the "project oriented" approach of building sectors makes complex the adoption of long term strategies. One consequence is the lack of knowledge and awareness about building life cycle energy costs.

Another important barrier is the complexity of dealing with existing buildings: lack of data, existing data are only available on paper, very simple and no automated installations, etc.

From the economical point of view, the current static energy price implies long amortization periods, which discourage investments in energy efficient. However, it is expected that in a near future energy price will be real-time changing and more close to the real one.

Impacts

Expected benefits and business opportunities to key stakeholders from using the results of the proposed RTD can be summarized in the following ones:

- Better knowledge about building life cycle energy performance and more affordable energy efficient buildings. Dramatic reduction in building project execution times and costs and higher quality of the buildings are expected because mistakes are avoided at design stage and decision making is based on more accurate data and the knowledge that was gained in previous projects.
- Implementation of the smartgrid concept. Higher integration of buildings in the energy networks will allow exploiting the building's energy generation and storage capabilities and their associated equipments, as future electric cars.
- New business opportunities for ICT, energy and building sectors. Due to the higher integration of the building life cycle process, new business opportunities in the context of building managements for facility managers and energy traders will be born. Also demand of ICT tools for building sector will be increased because their added value is raised through the interoperability among them. The market for BACS (Building Automation and Control Systems) will be increased because energy efficiency complements current market drivers, as comfort or security, and wireless technologies make easier their adoption in existing buildings.
- Higher sustainability with lower resource's consumption (i.e. travel, energy, etc) via changes to the way we work

Recommendations

Recommendations

Using the roadmap summarised in the previous chapter 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: policy, coordination, research & development, take-up, standardisation and education & training.

Recommendations 1-5: Research and Development

To put ICT at the core of future E2Bs and to enable them to reach their full potential, it is necessary to foster research into innovative ICT-based solutions and strengthen their take-up. This fundamentally means adding information to components, equipment and devices, and developing intelligence in integrated systems and services. As far as RTD is concerned, it clearly appears that it is today essential to reinforce multidisciplinary RTD involving researchers from the ICT, the energy (grid) and the building domains. Even if it still remains important to keep on research in new technologies and components, what it is drastically missing are tools and services for an integrated approach so as to reduce energy consumptions and GHG emissions from the diverse and fragmented building sector, and to face the increasing complexity of components and systems sustaining the future products and services, based on ambient information and knowledge, that will be deployed in the built environment for improved energy management. Such an approach must coordinate across various technical solutions, integrate engineering approaches with architectural design, consider design decisions within the realities of building operation, integrate green building with smart-growth concepts, and takes into account the numerous decision-makers within the industry. Eventually, *and as expressed in policies and coordination*, it is also fundamental to foster the use of national and regional programmes for the deployment and test of ICT-enabled research results (like large-scale pilots of energy management systems for public and commercial buildings) – establishing a link with the outcomes from national, European and international RTD.

RTD on enhanced integration, convergence and interoperability of ICT with the Construction artifacts, on the convergence of integrated building components, equipments and services with Smart Grid technologies and Internet-enabled applications, along with regulatory policies and environmental drivers, targeting the EE in future smart buildings, is to be developed around the following fundamental pillars (which represent the key topics the RTD should focus on):

- The **“intelligent” objects**: these objects must have embedded electronic chips, as well as the appropriate resources (including potential OS or platforms such as J2ME) to achieve local computing and interact with the outside, therefore being able to manage appropriate protocol(s) so as to acquire and supply information.
- The **communications**: these must allow sensors, actuators, indeed all intelligent objects to communicate among them and with services over the network. They have to be based on protocols that are standardised and open.
- The **simulation platforms**: fundamental at design and manufacturing phases (but also useful at operational phase, e.g. for best control strategy decision-making), such platforms should allow assembling in a modular and virtual way various BIM-oriented CAD tools, mock-ups and simulation software, relying on capacities of sharing various business-oriented models whilst ensuring a permanent interoperability thanks to standardised interfaces and data models.

Such a sharing of models should allow an improved benchmark and transfer towards construction stakeholders on the basis of adapted software and business applications.

- The “*smart BMS / ECMS*”*: relying on embedded intelligent objects and communications, they are to be new systems characterised not only by improved features (e.g. optimising the equation EE/duration/cost), but being able to communicate by embedding appropriate tags (RFID, etc.), and to improve global monitoring of complex assembling of products and equipments in the built environment. They have to potentially allow dynamic control & (re-)configuration of devices, through new algorithms and architectures for any configuration of smart devices to be able to dynamically evolve according to the environment or change in a choice of a global strategy. Ultimately, networks of such BMS/ECMS are to be the foundations of self-configuring home & building systems for EE, based on architectures where component-based in-house systems learn from their own use and user behaviour, and are able to adapt to new situations, locating and incorporating new functionality as required, including the potential use of pattern recognition to identify and prioritise key issues to be addressed, and to identify relevant information.
- The *multimodal interactive interfaces*: the ultimate objective of those interfaces is to make the in-house network as simple to use as possible, thanks to a right combination of intelligent and interoperable services, new techniques of man-machine interactions (ambient intelligence, augmented/dual reality, tangible interfaces, robots, and so on), and learning technologies for all communicating objects. These interfaces should also be means to share ambient information spaces or ambient working environments thanks to personal advanced communication devices. They should adapt to the available attention of users, and avoid overloading their "cognitive bandwidth" with unnecessary warnings or redundant feedbacks.
- New *construction business models*: indeed they must evolve towards integrating such a new multidisciplinary approach which will empower the scope and impact of future developments, improving this cooperation between ICT, energy and other sectors. A comprehensive and systemic view needs to consider future construction including life-cycle aspects (of buildings materials, from design to demolition), use (including on-site power generation and its interface with the electric grid), and location (in terms of urban densities and access to employment and services). When studying the range of technologies, it is important to consider the entire building system and to evaluate the interactions between the technologies. In this context, improved methodologies and techniques for holistic building analysis and new ICT-enabled technologies that optimize the overall building system are especially important.

I. Energy Efficient Design and Production Management

The first step in the future development and operation of energy-efficient buildings is related to the design phase, which must allow to include as much as possible and as early as possible energy-related issues, with compliance with user-oriented comfort expectations and constraints. In a second stage, production itself (should it be for manufactured components, on the construction site or at building operation phase) has to ensure that the configurations and (energy-oriented) options established at design time are not impacted or transformed during the production process.

* Building Management Systems / Energy Control Management Systems.

RTD focus is to be on:

- Building Information Models: the development of interoperable business applications and services (especially atop BIMs) will sustain the research/design/development of integrated design (*see next bullet*), enhanced diagnostic and renovation of existing buildings and infrastructures, performance prediction – e.g. simulations to assess variants of energy design solutions (related to environmental performance of buildings), tools for BMS design, tools for dynamic building performance evaluation at run-time, and allowing optimisation of production management based on multi-dimensional / multi-criteria constraints, etc.;

Configuration tools, connected to BIMs and e-catalogues, should allow managing and “playing” with energy efficiency related attributes of products and components, available in reusable form from catalogues, and characterising components and buildings with performance indicators which can be assessed using standardised methods.

- Design, simulation and optimization tools for Energy Efficiency: beyond BIMs focused on model-based design and engineering of buildings, ICT tools are to be deployed to design and plan buildings that fit within the environments in which they are built. Energy aspects will be integrated into various everyday design tools with minimum need to rely on advanced special purpose tools.
- Impact models: the mechanisms and potential impacts of ICT on energy efficiency are to be well understood and supported by causal models and evidence. This will enable grounded decisions to use ICT solutions for improved energy efficiency. RTD has to target conformance assessment tools, as well as visualisation of design solutions.

II. Intelligent and Integrated Control

The expected generalisation of “Positive-Energy Smart Buildings” - transforming buildings from pure consumers to “prosumers” (producers and consumers) able to generate more energy than using it (over a given period of time), is to rely on the development of sustainable connected buildings, homes and cities, empowered by ICT in the context of the merging of Ubiquitous Computing and the Internet of Things: the generalisation in equipping buildings with sensors, actuators, micro-chips, micro- and nano-embedded systems will allow to collect, filter, analyse and transmit data, and produce more and more information locally, to be further consolidated and managed globally according to business functions and services;

RTD focus is to be on:

- Increase of the autonomous lifetime of Wireless Sensor Networks (WSN), possibly based on harvesting techniques, and development of tools for continuous assurance of cost-effectiveness criteria and low-energy design strategies during the later phases of integrated energy conservation strategy.
- Cost-effective WSN-based monitoring and control solutions.
- Integration of sensors in the built environment (e.g. building components) – and appropriate sensors / actuators frameworks (*see section 2.3.5 too*).
- Development and implementation of meshed, self-adaptable and easy to install sensor networks (i.e. hardware and software, operating systems and protocols), improved diagnostics of network components, secure and low-consuming communications, etc..
- Solutions for building performance data analysis, holistic integrated BAC systems with anticipation (prediction) of energy demand and supply for an optimized control of energy sources and loads, etc.

A key point is generalised smart metering, relying on a recent political agreement reached on the proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings (recast): this new Directive foresees the obligation for EU Member States to introduce intelligent metering systems, and also recommends that the Member States can encourage the installation of active control systems that aim to save energy. RTD also has to consider opportunities and requirements for the development of software applications and tools for the purpose of compliance with the EPBD also bearing in mind the need for measured performance data.

III. User Awareness and Decision Support

Innovative, pervasive and friendly user interfaces are to be critical for construction stakeholders and global users' awareness. User awareness is a key factor for moving to eco-friendly behaviour. However, very few building-owners know what consumes the most energy in their building(s) and even fewer look regularly and accurately at the energy meter attached to their building since it remains an uneasy and tedious task. There is a need for new user interfaces/energy-displays that will provide attractive content at the appropriated time, through a motivational approach and with an intuitive and smart design. This is even more required in a context where stakeholders will have to deal with an increasing volume and complexity of all the information generated by the systems empowering our future smart buildings and districts, potentially coupled whenever required with the huge mass of information over the Internet, and also to deal with knowledge that is already available but not easily accessible. Overall, identification and smart visualisation of the right information to provide to the end-users, and the right way to provide it will benefit to many stakeholders, including end-users (occupants), building owners, facility managers, technology manufacturers, and utilities.

RTD focus is to be on:

- Prototyping of new tools providing more accurate information on energy performance of buildings through dedicated indicators, allowing benchmarking of historical data on the same building, continuous commissioning of performance of buildings equipments and components, and supporting user decision for reducing energy demand thanks to energy simulation features.
- Development of new user interfaces (e.g. dashboards) for energy use visualisation & feedback, control and simulation, accessible through various media (PC, phone, TV, etc.), providing the end-users with real-time information on their energy consumption, and empowering them to simulate different configurations and behavioural patterns and observe their impact.
- Analysis of how smart metering technologies can be exploited to effectively support energy visualisation.
- Understanding the role of graphic design in the presentation of energy feedback for behavioural changes, and design of advanced human-computer interfaces that better match the way our brain and bodies understand the notion of energy.
- Development of a common framework for services provision through multimodal channels.

IV. Energy Management and Trading

With the expected evolution (and indeed revolution) of ICT-empowered energy-efficient smart buildings, the built environment will play a new and key role in innovative distributed energy production, and new associated business models, moving from “end of pipe” buildings to active nodes in smart grids. They will permit to optimise the management of local energy/electricity production, storage and consumption, to erase consumption peaks, to deal with the management of some local coordination of the energetic system (e.g. between inter-connected buildings

belonging to a same node in the global Grid), while at the same time ensuring appropriate integration with smart energy grids - including securing the provision of the energy at any time (where ever it comes from - local or global), all this in a systemic approach and according to some various contexts (user profiling, security level, etc.).

RTD focus is to be on:

- Public-private cooperation models, required to boost research and experimental developments through the whole life cycle of the building, starting from the design and programming phase, where ICT tools will enable significant energy consumption reductions thanks to an appropriate design, to the building operation phase, where, as an example, advanced metering infrastructure could provide the framework for joint business models among energy utilities, telecom operators and building management companies.
- The development of a set of Energy Awareness Services, based on a ‘toolbox’ of components including: demand/supply real time control for energy generation/storage, pricing-driven dynamic optimization of BAC systems, automatic monitoring of consumption and transmission of consumption data; analysis and presentation of consumption data for access by tenants via Internet or other means; self-assessment scheme to assess the success of residents of a housing unit in reducing their energy consumption; improvement of heating controls and feedback to users of heating settings.
- The development of new value propositions, which are user centric (user awareness & user behaviour) – with seamless integration of the players in the value chain from modelling/design to building & maintenance, against current operational islands. There is a need for new cooperation models driven by new “marketable” products/services (including diagnosis & maintenance, continuous commissioning). For instance, some projects should leverage new technologies and practices like Automated Continuous Commissioning (ACC) for energy efficiency improvements, and new modelling techniques that predict building performance to aid managers in planning operational improvements and investments.
- The development of European Large Scale initiatives, instrumental in this area due to the high risk nature, and not only from a technological point of view. These initiatives need to be linked to long term roadmaps with clear and “reachable” KPIs (Key Performance Indicators) to make innovation happen. Also are to be considered privacy and security issues: typically (and as an example), the evolution of future buildings as data management infrastructures as a new paradigm to come requires that transparency and confidentiality in the use of the data are ensured, with clear social and political implications.

V. Integration Technologies

The ability to centralize and manage data embedded within building equipment is a challenge. Existing commercial buildings are full of technology and communication devices that have been installed ad hoc over time. These technologies – such as microgeneration to management technologies for lighting, heating and cooling systems, computer/Internet connections security devices and access control, fire safety control, and office equipment and appliance controls for new and retrofit applications – tend to operate on different protocol standards. In this non-integrated, multi-protocol environment, monitoring energy usage and device performance is difficult, if not impossible. Compounding this challenge is the issue with data. No one typically “owns” a given building’s system data, nor is a dedicated person or team typically assigned to monitor or use building data to drive building-management efficiencies. On top of this, there is often a lack of accountability between the building’s owner, operator and tenants, which results in a lack of contractual incentives to improve that building’s energy efficiency.

The main RTD focus is therefore on the development of:

- open frameworks for data collection and processing, to be installed in any built environment: such frameworks should support networked heterogeneous sensors and actuators (*with appropriate communication protocols*), allow assembling various “business” functions (*with easy evolution and extension capability thanks to a concept of service composition and event-driven management between modules*), be able to accommodate any hardware platform constraint (*memory, computing power*), and be executed in any environments and OS.
- Holistic and systemic approaches and cost-effective integration of “interoperable” & scalable ICT solutions combined with other key technologies (including those enabling smart grids and decentralised production). Based on the next generation of BIM (modular, extendable, based on W3C standards, able to map between different granularities of semantics), this should foster at the end multi-disciplinarity.

Recommendation 6: Policies

Regulations and financial incentives (e.g. taxation relief, energy feed-in tariffs) are common methods (regarding to energy efficiency policies and measures) used by governments to reduce or suppress costs of new technologies implementation at the consumer level. The take-up of new technologies can also be promoted via public procurement. Future policies should also be targeted at the EU level to cater for an increasingly open European construction market to drive energy efficiency in buildings.

I. Energy Efficient Design and Production Management

Building Information Modelling (BIM) in design stage provides comprehensive information on each building element and offers customised views to various stakeholders. This data can be further enriched to support the construction process and the subsequent building life cycle.

In reality, there will usually be more than one model interacting with each other on a complex project. However, these interrelated models do not necessarily contain all the required information for a project and effective communication between the models could be difficult due to the capability differences in their BIM software. Therefore, there is a need to establish policies about BIM adoption for all major projects. Firstly, standardised BIM and/or communication protocols between the models need to be enforced in construction, first in major projects, where multidisciplinary design teams will be able to develop requirements, design, construction and operational information for the whole building’ life cycle; simulations can be performed quickly and innovative solutions can be implemented. Secondly, the building authorities and industry should adopt digital code compliance checking for processing of building permissions.

Other perceived problems to the effective/proper use of BIM are the liability concerns. For instance, BIM modellers could be legally liable for designing a model to its full potential which goes beyond acceptable boundaries between the stakeholders involved in the model. Also, there are potential issues around the ownership/management of one or more models and of documents derived from it that would need to be addressed. Therefore, the protection of Intellectual Property Rights (IPR), with regards to semantically rich information (BIM), is necessary in order to promote and stimulate application of BIM.

II. Intelligent and Integrated Control

It is necessary to provide effectual policies (and incentives) at European level to how ICT as an enabler can help to promote energy efficiency and encouraging energy-saving behaviour. The EC should try to formulate policies from the Executive Agency for Competitiveness and

Innovation (EACI) (previously known as the Intelligent Energy Executive Agency) working on sustainable energy in buildings projects such as EU's SAVE Programme, etc. This also includes taking a close look at technologies that limit energy intensive behaviour (i.e. time of equipment usage limiters, thermal regulation of room temperature, motion/illumination sensors, etc.).

Policies for the maintenance of equipment in order to avoid a progressive loss of its efficiency need to be improved. Energy-related information needs to be protected against misuse and loss, unauthorised access, modification and disclosure. This is related to e.g. secure methods of communication, back-up and recovery systems operation.

III. User Awareness and Decision Support

In the area of energy-user awareness and decision support, smart metering plays a key enabler in influencing people's behaviour and changing their energy consumption patterns. At present, the motivations and scale of smart-metering deployment greatly differ across countries in EU. Following legislations to liberalise the EU energy sector in recent years, it would be feasible for EC to setup a working committee to devise a common policy framework for smart metering in EU. The framework is expected to cover technical, social and economic issues, which include benchmarking of existing experiences by considering local specificities (e.g. energy prices, incentives, etc) and the views and interests of the various stakeholders in the energy supply chain. It will also take account of future technological advances as well as possible schemas for the evolution of energy pricing. The outcome is likely to favour the large deployment of smart meters thus contributing to the reduction of primary energy consumption, while supporting more competitive market environments. Another major impact is to provide the majority of consumers with better information on energy usage to encourage energy efficient and low-carbon behaviours.

Finally, the policy makers and regulatory bodies can impose possible obligations and/or incentives for manufacturers that could provide smart-metering tools that are easy to operate and with good visualisation of energy consumption.

IV. Energy Management and Trading

The dynamic adjustment of energy prices to consumers is not a new concept, and current technologies have made dynamic pricing not only widely possible, but also commercially feasible. It will increase customer's motivation to use energy at the time of minimum cost or to consume less energy. The novel dynamic pricing-driven policies directed on business models of energy providers/distributors will significantly help to save energy.

V. Integration Technologies

The benefits from usage of ICT in the construction industry are showing as improved energy efficiency of buildings and productivity of the sector itself. However there is still lack of evidence-based (particularly quantitative measures) to assess energy efficiency impact of ICTs in buildings. This has to be improved in order to promote ICT for construction and to support related policies and measures. The Technology Foresight approach could be used by policy-makers to better assess both the qualitative and quantitative potentials of ICT4EE in buildings. With these quantitative assessments, policymakers could set more detailed targets meeting the EU's '20/20/20' roadmap.

Construction in Europe is still a very local activity, not only due to site conditions and obvious need for local supplies, but also subject to regional regulations and business practices. Energy efficiency and advanced use of ICT are potential competitive advantages that could best flourish

in an open market. The policy should be towards an increasingly open European construction market.

Performance-based building regulations, where the performance criteria rather than prescribed solutions are stated, should be further supported. This would stimulate building developers to search for an optimal efficient building design and operation approaches and to come up with innovative solutions that can best meet the objectives of the regulations as well as the needs of building's stakeholders.

Building's energy performance labelling will ease the customer's choice of best/suitable building selection on the market. These buildings inherently employ the best available energy efficiency related technologies and practices, which thus provides the market driver for energy efficiency adoption. The common European regulation and further legislation in this area is essential.

Recommendation 7: Coordination

The role of coordination activities is to support research activities and policies via networking, exchanges, trans-national access to research infrastructures, studies, conferences, etc., through some potential structured and nurtured approach. Key generic actions can be envisaged as follows:

- Increasing synergies and potential collaborations between multiple actors and partners in the fields of building construction, energy efficiency and ICT - especially relying on the establishment of inter-relationships between PPPs (Public-Private Partnerships), for instance typically:
 - ARTEMIS, having established a priority research topic within its work-programme dealing with Embedded Systems for Sustainable Urban Life, including new electronic devices for supporting Energy Efficiency in Buildings among other services such as security;
 - and E2B, which objective is to deliver and implement building and district concepts that have the technical, economic and societal potential to cut the energy consumption in existing and new buildings by 50 % within 2030, thereby contributing to improve the energy independence of EU, through a holistic combination of technologies that are needed to realise the building concepts, including ICT as a key element for improving energy efficiency in buildings and districts.
- Providing incentives to favour information sharing and collaborative developments at a trans-national level (as a means to support collaborative European RTD, but taking into account specificities of countries and providing opportunities of sharing of experiences and good practices), as well as international cooperation.
- Supporting the development and integration of technical ICT-based solutions, especially by:
 - accompanying the construction industry in the innovation process (after the RTD phase), by providing a coherent European framework for developing common approaches, with common European standards, and the localisation and adaptation of common solutions which have to be compatible with varying environmental contexts, social (user) preferences and regulatory aspects at national or regional level across Europe; *one of the key points here is to overcome the standardisation barrier, with means to stimulate/look at some potential standardization of building systems in standards bodies;*
 - valorising the ICT-based solutions by helping and pushing evaluation and certification of packages, digital services (in buildings) and processes – overall with the development of labels. The evaluation should be relying on the usage value of technical solutions, for instance through large-scale pilots, user panels, development of showrooms, education, etc.

- Propose instruments to create a critical mass of research, development and innovation at EU level in the areas of ICT-based technologies and services for energy efficiency in buildings, with the establishment of a favourable environment for participation and training of construction SMEs that could act as “front-runners” for the prescription and deployment of new optimised solutions in buildings.

Getting into details for each of the RTD categories, the following recommendations can be provided:

I. Energy Efficient Design and Production management

Common analysis of current situation and planning of further actions should be performed as part of the development of innovation roadmaps, with the identification of needs for migration strategies, methodologies and guidelines. The development can be based upon known best practices that encapsulate the design, deployment and management of energy efficient systems. Benchmarking process, i.e. the identification of the best practices and measures in the construction sector in different environments, will outline the targets for technological migration.

II. Intelligent and Integrated Control

Coordination activities (e.g. workshops, meetings with related stakeholders) with experience, knowledge and know-how exchanges are effective instruments for best practice results dissemination and collection of a new knowledge – especially in this area where RTD is considerably active. An example of such a coordination action may be a series of workshops with the subject as “implementation of the building automation system with proper connection to the smart grid”.

III. User Awareness and Decision Support

In order to coordinate the development of common user interfaces it is essential to create working groups composed of user-centred designers, ergonomists and end-user representatives. The outcome from these working groups will support the definition and deployment of more efficient user interfaces and associated tools for energy awareness, customized to the end-user needs. This could be organised, along with live experimentations (in vitro & in-vivo), according to some “Living Lab” approach.

IV. Energy Management and Trading

Coordination of energy demand response (in the context of collaboration programs) should be performed through deployment of information, gathered from interviewing building administrators/managers, facility occupants and energy providers, on practice. As a result, the changes in energy usage behaviour of the end-users will go along with changes in the price of the consumed energy over time. The incentive patterns of payments (e.g. discounts) should be designed to encourage consumers for lower energy use at the peak-time (high) prices or when energy-supplying systems are overloaded. It will also stimulate building stakeholders to implement the local energy generation technologies in order to reduce dependency from energy providers. .

V. Integration Technologies

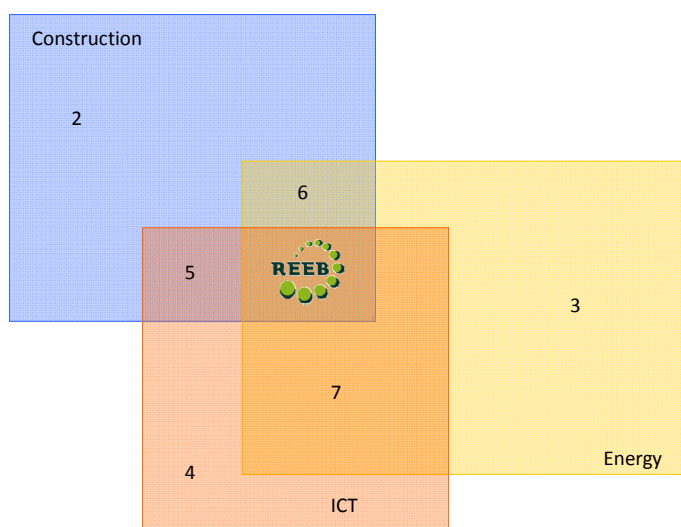
The large variety of environmental conditions and regulations in the EU is undermining the attempts to develop single common standards for tools and applications used for achieving energy efficiency in buildings. Nevertheless, an active coordination and promotion of the convergence of standards which are prepared by different communities (e.g. separate countries,

similar climate regions, etc.) must be achieved. It can be done by merging forces of researchers and industry partners under umbrellas of related technology platforms, establishment of single European communication network for all spectrums of building stakeholders and energy providers/distributors, and standardisation of technology development tools.

Recommendation 8: Take-up

Awareness and Dissemination

In order to deal with the multidisciplinary and transversal approach needed for covering the whole supply and value chain, an exhaustive identification of potential target groups and stakeholders involved in the three different sectors within the ICT4EEB scope has been done, according to the following categories:



Mono-sector stakeholders	
2 Construction	Large construction companies and SMEs, architects ... Building owners, including public authorities.
3 Energy	European energy sector: energy management agencies, energy service providers, utilities ...
4 ICT	IT and business services companies...
Dual-sectors stakeholders	
5 ICT + Construction	Facility management companies, building management systems providers, dataware house product developers...
6 Energy + Construction	Installers and providers of energy efficiency services for buildings, energy audit companies...
7 ICT + Energy	Supplier of energy solutions with embedded ICT, smart meters manufacturers, energy box manufacturers ...
All-sectors stakeholders	
1 ICT + Energy + Construction	Certification and standardisation bodies, research community...
Non sector-related stakeholders	
0 Non sector-related	Local, National, European authorities, policy makers, decision makers...

Figure 33: Identification of stakeholders for ICT4EEB

Since the building market is characterised by its diversity, complexity and fragmentation, dissemination and awareness actions must be taken aimed at driving the sector to a new knowledge-based industry that adopts tools from other sectors. Besides, social awareness needs to be improved by promoting changes in collective behaviours.

Individual analysis should be made related to age, gender, social category, etc. and dissemination activities should be performed to find pattern groups or individuals willing to test the new technologies, with respect to the social acceptance. Thus, involving individuals in a very early phase will be a powerful way of guaranteeing a successful final acceptance, helping to prepare the future new markets, and simplifying the final dissemination process.

Synergies at National and European level

Energy Efficiency in Buildings is a real concern in Europe, where 23 Member States have specific national programs addressing this issue. However, they have different visions and strategies. It is necessary to address the whole value chain in a homogeneous and sustainable way during a long period. Even at European Commission level, initiatives should be better coordinated among different authorities.

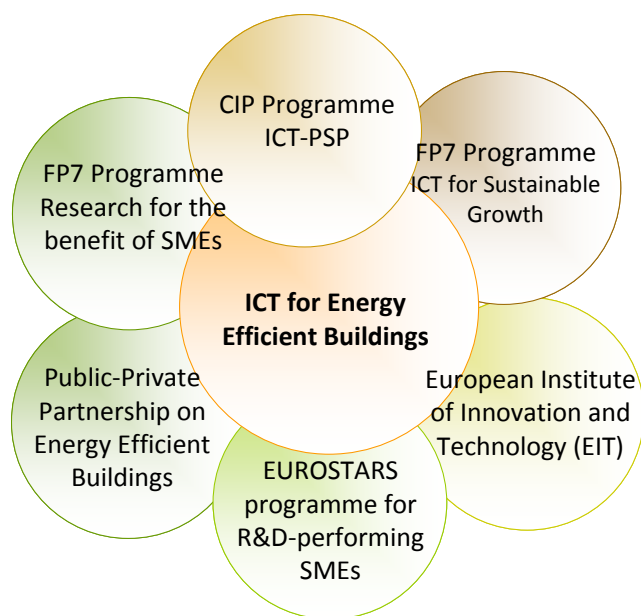


Figure 34: Main existing ICT4EEB-related RTD initiatives at European level

These synergies should be shared among ICT, Energy, Construction and other sectors. Coordination with other European Technology Platform, such as Construction, Photovoltaic, Thermal Solar, Wind, Steel, etc. is also needed. Energy efficiency goals should be set with a systemic approach that includes economical and social aspects as well as technological aspects.

Replicable Real Scale Pilots

Research results should be validated at real scale and replicated across Europe, so that greater impact can be achieved at shorter term. As a start, it is necessary to characterize the current building stock, evaluating the renovation potential of existing buildings. Replicability will be increased with the involvement of public-owned buildings, such as hospitals, schools, universities, social housing, etc.

Pilots at district level are recommended to achieve higher degrees of energy efficiency, as the use can be optimized at different levels: the whole district, groups of dwellings, or at building level. This approach is more efficient and less expensive than individual approaches.

Common Methodologies

The challenge has a high degree of complexity, and in the past different approaches have been followed to deal with it. From these approaches a collection of best practices have been identified. Nevertheless, a common methodology is needed to measure achievements and for implementing devices, systems and services.

Experiences sharing can speed up pre-normative research towards standardization of components and systems compliant with building codes and electrical normative. Activities must be developed on a coordinated basis within national and international certification bodies.

Key recommendations

Summarizing, key recommendations for take-up activities are:

- Improve user awareness through dissemination campaigns with regard to best practices and RTD projects results.
- Enable a holistic approach by identifying and bringing together all related stakeholders within technology platforms, working groups, associations and international fora, including public authorities, standardization bodies and policy makers.
- Promote replicable real scale pilot projects both at building and district levels.
- Establish common framework and methodologies for energy efficiency-related measurements and implementations within pilot projects.

Recommendation 9: Standardisation

One of the most relevant capabilities of ICT for Energy efficiency in Building is their potential to automate the data flows among the different stakeholders of the building sector value chain that are involved in building's life cycle. But this automation is only possible when the interaction among them is based on standardized communication mechanisms. Standardization initiatives have to focus not only in the “digital” communication protocol (physical layer, data structure...), but also have to extend them to the semantics of the building concepts that are interchanged.

I. Energy Efficient Design and Production Management

Enhance the scope of IFC, the buildingSMART BIM open standard, to cover energy efficiency during whole building life cycle.

Energy efficient building design and production require the collaboration of several specialized teams. Every team uses a toolkit of different software applications, which need detailed description of the building and its installations. The availability of an open and standard BIM would make this collaboration more agile and efficient. Current IFC versions are mainly oriented to building design task and are very useful to automatically feed these tools with the building model that has already been defined by other tools. For example, the engineers who design the HVAC system can import into their CAE tools the BIM that has been created by the architect's CAD tool. However, IFC needs to be extended to better support energy efficiency oriented building life cycle, from building design to building operation. For example:

- Standard definition of passive and active systems for energy efficiency.

- Standard methods for the integration of BIM with real time data.
- Standardization of maintenance information.

Promoting component based building configuration tools

Currently, building installation's design is based on the selection and integration of existing components (boilers, valves, pipes...). This approach is extending also to the building design itself. Building process is evolving from mainly handmade activities toward industrialized tasks, and it is expected that this evolution will be even speeded up in the future. This evolution of the building industry will imply the adoption of component oriented building design. Current building practices allow defining from scratch any building component. However, the industrialized approach requires basing the building design on catalogues of available products and building solutions that have to be personalized and adapted to the specificities of the new project. This new approach requires development and standardization of **digital catalogues**, in such a way that manufacturers can make available the specification of their products to all the design tools with only one catalogue definition, and design tools developers only need to implement one interface to read the catalogue provided by any manufacturer.

II. Intelligent and Integrated Control

Secure and privacy oriented energy data communication standards

Usually, current BEMS are not very sophisticated and are isolated systems that are based on a limited numbers of sensors and actuators. In a near future, these systems will be more intelligent and integrated in multipurpose building management system (energy, security, entertainment...), and will collect information from much more sensors and manage much more actuators. In this context, more robust control and monitoring protocols will be required. These protocols should be able of managing the uncertainty and data incoherencies that are inherent to very large communication networks.

At the same time, it is envisaged that data about energy management in buildings will be exploited by internal systems, but also by external ones, as repositories of energy consumption data in order to support diagnostics and identification of well or poorly performing buildings. Consequently, special attention should be paid to data privacy, in such a way that data can be traced without compromising building users' privacy.

Standardized APIs for energy simulation tools

In order to increase the accuracy of the control actions that are suggested by BEMS, it is needed that the impacts of these actions are simulated before executing them. Consequently, the next generation of BEMS will integrate with energy simulation tools. Currently, these tools are mainly oriented to design activities, but they will need to be adapted for control tasks and be opened to feed them with real time data. Consequently, standardization of the API that will be provided by these tools will make easier the evolution of BEMS toward more intelligent systems and selecting the best simulation tool for every building control system according to its specificity.

Harmonization and integration of existing monitoring and control standards.

Nowadays there are several monitoring and control protocols (KNX, LonWorks, X10, HomePlug, ZigBee...) that coexist in the market of building automation. Several of these protocols already support different communication media, as Ethernet, powerline, radio frequency or twisted pair, offering the possibility of deploying wired and wireless monitoring and control networks. However these protocols are not interoperable. Until now, while BEMS have been isolated systems, this lack of interoperability has been a problem that only concerned the maintainability and extension of the systems. However, the integration of BEMS with other

building management systems will require standardized integration protocols that are able to integrate the different BEM architectures in a global system.

This need of integration with the different existing monitoring and control protocols is reinforced by the increasing complexity of building control strategies. The “brain” of the future controls system will be more complex than the current ones and will include deeper domain knowledge. Consequently, it could become an independent component of the control systems that would have to be able of operating with different monitoring and control architectures.

Energy efficient wireless communication protocols

The flexibility that is provided by wireless monitoring networks will make them very common in future BEMS. In many cases, one of the main weaknesses of these networks is the autonomy of their sensors when they are fed by batteries. In this case, the main energy consumption is due to the emission of messages. Consequently, low energy consumption communication protocols (ZigBee, 6LoWPAN, EnOcean...) should be promoted in building sensing applications in order to increase the batteries autonomy and reliability of the system and avoiding too frequent maintenance actions.

III. User Awareness and Decision Support

Energy performance indicators

There is a well-known sentence about improvement of processes: “*what is not measured cannot be improved*”. However, measuring is not enough, building users need to perceive and to understand these measurements and evaluate them according to the specificities of its building characteristics and use (locations, building type and use...). This aim has to be supported by standardization actions at different levels:

- Data collection: What parameters have to be measured? How they have to be measured (precision, sampling time, ...)? When (time in day, period in the year, ...)? As it was said in a previous section, the harmonization and integration of existing monitoring and control communication protocols will be required to make possible the definition of a standard data collection process for energy performance evaluation.
- Performance measurement: What are the performance indicators? How will the collected data be managed to calculate the performance indicators?
- Reference values: What will be the reference values of these performance indicators that will allow the building users to know if their behaviour and building performances could be improved? One of the most powerful tools to make “visible” the energy performance of a building is comparing its performances with the performance of similar buildings. This benchmarking process requires standardizing building characterization and defining a standard communication protocol that allows collecting the information from a large community of buildings (neighbourhood, city...) and storing and consulting it in a data server.
- Visualization: How is this information transmitted to building users and building managers? Standard communication protocols have to be defined to make possible that smart-meters and BEMS are able to communicate with building users through very familiar devices as smart-phones, TV or tangible interfaces in order to inform them about over-consumption or possible actions to increase energy efficiency of the building.

Standardized collection of data about buildings energy performance has also a parallel exploitation as a data repository for decision making by the authorities and building designers. If granularity of the information is detailed enough, it could allow prioritising the policies and regulations to increase energy efficiency in buildings and correcting common mistakes in exiting buildings when they are refurbished or when new ones are designed.

IV. Energy Management and Trading

Building's integration in the Smart Grid

The building's integration in the Smart Grid will imply that a building will be an active node in the power grid, which is able to adapt its energy demand and generation to the grid state. From the ICT standardization point of view this change will imply that new bidirectional communication standards have to be defined:

- The utility has to be able to inform the “building” about energy supply contractual conditions, dynamic energy prices and particular network operation conditions that could require a reaction by the building.
- The “building” has to be able to inform the utility about current and future energy generation and consumption capabilities.

But this gateway of the building with the grid has to be also integrated with the internal BEMS, in such a way that the building can automatically react to the new power supply conditions, for example by switching off some devices.

There are already some emerging initiatives in this line, as OGEMA (Open Gateway Energy Management Alliance).

V. Integration Technologies

Open Platform for energy management in buildings

Nowadays energy management along building life cycle is done by more or less independent software applications, with light integration among them. However, the increasing complexity of the processes and their automation is demanding a tighter integration. The definition of an open holistic reference architecture for building energy management that defines the main components of the system and their standardized interfaces supporting model views would make it easier to satisfy this demand.

Collaborative design environments

Until now, the main standardization initiatives about information sharing have been supported by digital files and messages. However, the tighter coupling of building's design teams is demanding more dynamic cooperation mechanisms that avoid the problems that are inherent to this communication channels, like data duplication and incoherencies among versions. Consequently, it is necessary the evolution of these standards, as IFC BIM, towards shared database supported standards, in such a way that the referred problems are avoided. In this new approach, not only technical information has to be addressed, but also “data management” aspects, such as tracking of design changes and their contractual status.

Very long time data archival

The life time of a building is in the range from 50 to hundreds of years. Time between major refurbishments is typically tens of years. However, data and storage media standards are evolving in a far faster pace. The proliferation of model- (BIM-) based tools increases this problem even more: the software applications, which could potentially re-use archived data, are also evolving and generating more complex data. As a consequence, archived data is not accessible after a long time - unless it is frequently refreshed which may not be feasible due to costs and long payback time. This problem hampers the use of sophisticated ICT tools because data for archival is required at low semantic level, usually as documents. Consequently, information management mechanisms that warranty backward compatibility with previous BIMs

are required in order to take advantage of their huge potential in building life cycle information management.

Promotion of building certification standards

Well known and trustable energy efficiency certification standards are very powerful drivers to promote energy efficient buildings. Currently, there are several independent certification initiatives in Europe. This disparity of certifiers make very difficult comparing building performances in different European regions. The harmonization of these initiatives should be encouraged in order to achieve a unified European building certification standard.

From ICT point of view, the automation of the certification process through its integration with the building design tools and monitoring systems should be encouraged. These systems should be complemented with public certification registers that provide transparency about building energy performances and inform building owners about the relevance of energy efficiency in buildings.

Reference values

Data repositories about minimum legal requirements for energy efficiency in buildings and typical energy consumption of office and home equipment should be created and made accessible through standardized interfaces. The availability of these data would make it easier to understand the performance of the building and to improve it.

Recommendation 10: Education and Training

At present, the related information and technologies about energy efficiency are growing very fast and getting more and more complex. To handle and disseminate the information effectively, an efficient way of information management is needed. The success of energy efficiency is very much dependent not only on overcoming professional barriers but also on sharing information. The diffusion of the knowledge led to well informed and committed stakeholders and to the improvement of energy efficient solutions and practices. To improve the capacity-building activities it is important to promote and harmonize co-operation in education, training and research. As energy efficient building is evolving rapidly as an advanced academic field so that the content of a textbook tends to get outdated quickly, the Internet will play an increasingly important role for supporting the education and training in this field. The main intention is to focus on variable virtual learning centre, for an open, distant and flexible learning and teaching environment, using effectively integrated IT infrastructure which results into powerful technology transfer mechanism of knowledge and experience, with a learning and working process tools through web-based platforms (multipoint conferencing unit, virtual seminar room, videoconferencing service) that would support a virtual learning centre. It is also important that in order to promote effectiveness of energy efficiency services and energy awareness, authorized institutions should extend official certificates in energy efficiency training. Institutions with experience in specific EE areas can provide a vivid learning experience with laboratory support and offering updated learning programs. Standard performance evaluation of EE implementations should be part of the training process. In general basis it is required to increase awareness of the issues, opportunities and solutions in all educational levels (universities, technical training and business education) by optimization training through basic tutorials or training simulators.

I. Energy Efficient Design and Production Management

The update design technology requires a powerful energy simulation tool that can support evaluation of the energy building demand and energy-supply technologies supporting the various

decisions taken through the life cycle of building design and operation. Some important aspect to be managed with the software support can be the behaviour of building control systems and the resultant impact on energy use, peak demand, equipment sizing and occupant comfort to provide performance insights. It is of vital importance that the learning techniques open the simplest learning process for different professional areas, to understand the best use of those extended software programs, the shortcoming should be overcome by program improvement driven by the market and users.

Practitioners should learn to work within the tools limitations and profoundly understand its role in the design process, taking into account that a successful design depends not only in the advance software but on how good the designer has been applying the technology and the energy analysis tools during the design process. The use of tools in energy integrated design has its limitations, the design methods and tools are mainly developed in parallel and independently, most tools address mainly detailed design, while only few support other design phases. The basic Integration problem is that a common model and interoperability methods are missing. A horizontal integrated information chain is not a reality and many errors prone and time consuming information hand over procedures is still needed. Vertically integrated life cycle design is still missing due to the lack of sufficiently powerful data models, inadequate interoperability and fragmented design cultures across various disciplines. It is the main task to provide the optimal technical training to raise the level of profitable use of design tools and the optimization of the professional quality support.

It is expected that the training techniques should be enhanced and up to date concerning the software tools and their interoperability as well as the different concise applications related to modelling and simulation capabilities, the framework of the learning interface should adapt interactive components to display real cases and interactive applications for a realistic training work. Such interfaces can work adapted to building systems to display the real-time resource use and other energy efficiency features in the building, this would extend the learning work between theoretic and practice application, bringing up the importance of the real-time resource. GUIs interfaces for generation of the building geometry and navigation in complex information spaces, mapping and filtering of data for different design aspects and stages can be also a very useful training tool.

II. Intelligent and Integrated Control

Knowledge processes through platforms can be useful for an integrated control mapping training; the compliance of the integrated control technologies should be interrelated to complement a central control for an optimal training. The insufficient interoperability of the energy sub- systems can complicate the integrated control and data transmission between tools.

The whole building supervision by intelligent systems which are able to combine information from all interactive devices, is a functional integrated production of systems concepts, each of them and the corresponding interrelation are to be analyzed for the training proposes. It is of main interest to develop training techniques that integrates all the control systems for general overview of the process as well as the updated tools applications. The Automation systems with all the methodologies, procedures, equipments, actuators and systems technologies with the optimization methods and sensors algorithms applications, the monitoring diagnostic interpretation, wireless sensor networks operating systems, network design, as well as lessons for Smart Grid intelligence and smart meters networks analysis can be optimized training themes.

III. User Awareness and Decision Support

Performance analysis tools tag and measure energy performance level, the prediction measurements and simulations through the building life cycle, the benchmarking within similar buildings serve as a basis for continuous improvement in energy performance of buildings. Energy awareness through smart metering tools can generate the visualization of the energy usage and performance data analysis; it is the training task to bring to all stakeholders the appropriate usage of those real-time visualizations and graphic interfaces through right interpretations and analysis applications. Training courses for building owners and facility managers -with potential adaptation for students (European-level courses) and vocational training for engineers- are recommended, in Energy efficiency monitoring methods based on key features of Best Practice and past performance comparison examples to make realistic assessments of relative performance and decision support tools (baseline and track performance, identify saving potentials and set targets, identify problems and communicate results and achievements) using configuration tools for performance and decision support to optimize energy efficiency in buildings.

IV. Energy Management and Trading

Energy management is a very predominant and growing demand sector, open to many highly qualified engineers; the management is responsible for the whole well development of the energy- efficient building. The main interaction lies between the building as a structure and the technical facilities with special impact in comfort, energy systems integration, and life cycle, functional and economic aspects. It is important to ensure that the energy management training is update and optimal adapted to current practice. Most building energy management systems are operated using design software programs that are capable of providing feedback on system operations and energy consumption. Most types of building energy management software also allow operators to make changes to building automation systems, though some may require changes to be made manually. Many building management professionals have both hands-on and technical training in energy conservation and building operations. The software used to control building energy management systems may gather data from a variety of information sources. They will typically measure temperature changes, humidity levels, and occupancy patterns to calculate energy use. Many energy control systems also measure air quality and carbon dioxide levels to help maintain healthy buildings, these programs can recommend techniques to maximize occupant comfort and function while minimizing energy consumption. Building energy management systems also monitor operational failures and routine maintenance tasks. To maintain a good quality of control it is important the training of professional support in the technical management tasks and on specific training for those operations. Management training application for software platforms, training for software user interfaces applications; interpretation of building performance data generated by the software, management information systems applications, energy usage management for the whole building cycle and decision support through recommended lesson on high performance of buildings and real time application for the whole building management and creative design for configuration management training.

V. Integration Technologies

The great complex performance of integration and the interoperability increase the difficulty in the technological training development, lack of skilled professional in the area and lack of data to manage advance control systems. It is expected that the emerging tools will be capable to integrate all the energy subsystems and open a new integration update process in training. Training in schematics process of the building construction and it's sequence of operation within a system integration to provide understanding of the incentives of various stakeholders and how

to align them in order to achieve more holistic approaches through recommended training lessons in Process and system integration are recommended and Network standard protocols, data processing unit's applications and data exchange interfaces available and the interpretation of data processing to support the Integration application knowledge through training on integrated model- based software tools with integrated workflow models.

Bibliography and Abbreviations

Bibliography

- 21 (Eco)Visualizations for Energy Consumption Awareness. flowingdata.com/2008/04/03/21-ecovisualizations-for-energy-consumption-awareness/
- A. Costa, M. Keane, P. Raftery, J. O'Donnell; "Key Factors – methodology for enhancement and support of building energy performance", 2009, National University of Ireland, Galway, Ireland; zuse.ucc.ie/iruse/papersNew/AndreaGlasgow.pdf
- A. Neto, F. Augusto S. Fiorelli, University of São Paulo; "Use of simulation tools for managing buildings energy demand"; gundog.lbl.gov/dirpubs2/BS07/eplus_494.pdf
- Alanne and A. Saari, Distributed energy generation and sustainable development, Renew Sustain Energy Rev 10 (2006), pp. 539–558;
- ARTEMIS Multi-Annual Strategic Plan and Research Agenda 2009. ARTEMIS Joint Undertaking. ARTEMIS-IRC-02-V061008-draft (MASP). 06/10/2008. www.artemisia-association.org/attachments/583/ARTEMIS_MASP_2009_Draft.pdf
- ARTEMIS SRA, First edition, March 2006. www.artemisia-association.org/downloads/SRA_MARS_2006.pdf
- ARTEMIS Workprogramme 2009. www.artemis-ju.eu/call_2009
- Bazjanac, Vladimir. Building energy performance simulation as part of interoperable software environments. Building and Environment 39 (2004) 879 – 883. gundog.lbl.gov/dirpubs/interop.html
- Bazjanac, Vladimir. Virtual Building Environments - Applying Information Modeling to Buildings, in A. Dikbaş and R. Scherer (eds), eWork and eBusiness in Architecture, Engineering and Construction, Proc. fifth European Conference on Product and Process Modelling (ECPPM), Istanbul, TR:41-48. Balkema. ISBN 04 1535 938 4. 2004.
- Berg Insight's Smart Metering in Western Europe report 2009 berginsight.com/ReportPDF/ProductSheet/bi-sm6-ps.pdf
- BERR Dynamic Demand Case Study. <http://www.intellectuk.org/content/view/3789/84/>
- Better buildings through energy efficiency: A Roadmap for Europe, Klinckenberg Consultants, Eurima Blueprint Project, Meerssen, the Netherlands, June 2006 www.eurima.org/uploads/pdf/bobontheroad/EU_Roadmap_building_report_020307.pdf
- Better ways to collaborate. The Economist Technology Quarterly. London. The Economist. December 2009. www.economist.com/sciencetechnology/tq/displaystory.cfm?story_id=15048827
- Bozdağ, Ö & Seçer, M. Energy consumption of RC buildings during their life cycle. In: Sustainable construction, materials and practices (SB07). ISBN 978-1-58603-785-7. Pp. 480-487. 2007. books.google.fi/books?id=SF4zVXee7EC
- BREEAM: the Environmental Assessment Method for Buildings Around The World. www.breeam.org
- Building Energy Software Tools Directory. U.S. Department of Energy. apps1.eere.energy.gov/buildings/tools_directory/
- BuildingSmart Alliance www.iai.org.uk, www.buildingsmartalliance.org
- BuildingSmart, International Alliance for Interoperability, www.buildingsmart.com

- Cao, Q.; Abdelzaher, T.; Stankovic, J. and He, T. The LiteOS Operating System: Towards Unix-like Abstractions for Wireless Sensor Networks, In Proceedings of the 7th International Conference on Information Processing in Sensor Networks (ACM/IEEE IPSN), 2008.
- Capturing the European energy productivity opportunity. McKinsey&Company. September 2008
- Carey, Andrew and Parsons, Simon “Improving sustainability through the 21st century workplace and IBM’s vision of the office of the Future”.
http://www-935.ibm.com/services/us/gbs/bus/pdf/smarterofficepdf_f3.4.09.pdf
- Cascadia Consulting Group, Statewide Waste Characterization Study (California), December 2004. www.ciwmb.ca.gov/ConDemo
- Central Statistics Office (Ireland). Transport 2007.
www.cso.ie/releasespublications/documents/transport/2007/transport07.pdf
- CIB, Intercational Council for Research and Innovation in Building and Construction.
www.cibworld.nl
- COBA, Connected Open Building Automation. www.coba-group.com
- COM (2006) 545 final. Action Plan for Energy Efficiency: Realising the Potential. Communication from the Commission. Commission of the European Communities. Brussels, 19.10.2006. ec.europa.eu/energy/action_plan_energy_efficiency/doc/com_2006_0545_en.pdf
- COM (2007) 723 final. Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions - A European Strategic Energy Technology Plan (SET-Plan) Brussels, 22.11.2007.
europa.eu/scadplus/leg/en/lvb/l27079.htm
eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0723:FIN:EN:PDF
- COM (2008) 800 final. A European Economic Recovery Plan. Communication from the Commission to the European council. Brussels, 26.11.2008.
ec.europa.eu/commission_barroso/president/pdf/Comm_20081126.pdf
- COM (2009) 111 final. Communication from the European Commission ... on mobilising Information and Communication Technologies to facilitate the transition to an energy-efficient, low-carbon economy.
cordis.europa.eu/fp7/ict/sustainable-growth/key-docs_en.html,
ec.europa.eu/information_society/activities/sustainable_growth/docs/com_2009_111/com2009-111-en.pdf
- Crayton, Tim The Design Implications of Mass Customization. Design Intelligence. May 2001.
www.di.net/articles/archive/2054/
- Darby, Sarah. The effectiveness of feedback on energy consumption. A review for Defra of the literature on metering, billing and direct displays. April 2006
- DEGLER, Scott (Honeywell). Building Automation Control Trends, presented on 14th of November 2007. secure.csg.org/NASFA/Regional%20Meetings/East/_ControlTrends3.ppt
- Deutsche Gesellschaft für Nachhaltiges Bauen (German Sustainable Building council).
www.dgnb.de
- Directive on Ecodesign requirements for energy-using products (EuP). European Parliament and the Council. July 2005. ec.europa.eu/enterprise/eco_design/dir2005-32.htm
- Directive on the Energy Performance of Buildings (EPBD). European Parliament and the Council. December 2002. www.buildingsplatform.org

- Distributed Database Concepts, Oracle.
download.oracle.com/docs/cd/A58617_01/server.804/a58247/ds_ch1.htm
- Doukas, H., Nychtis, C. and Psarras, J. (2009) Assessing energy saving measures in buildings through an intelligent decision support model, *Building and Environment*, 44, 290-298
- E2B EI - European Initiative on Energy Efficient Buildings. Scope and Vision. V01. 31/01/2009. [www.e2b-jti.eu/documents/Scope and Vision_EI.pdf](http://www.e2b-jti.eu/documents/Scope_and_Vision_EI.pdf)
- Eastman, C. et al., 2008. *BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors*, John Wiley & Sons.
- ebXML. <http://www.ebxml.org/geninfo.htm>
- Electric Power Research Institute, "Advanced Metering Infrastructure (AMI)", Feb. 2007, www.ferc.gov/EventCalendar/Files/20070423091846-EPRI%20-%20Advanced%20Metering.pdf
- Electricity Traffic Light for End-Users.
http://www.ukpia.co.uk/Press%20releases/emessage/PM%20GB%202%20-%202008%20CeBIT_EnBW_eMessage.pdf
- eMobility Strategic Research Agenda - Staying ahead with SET. eMobility - Mobile and Wireless Communications Technology Platform. Version 7. December 2008.
www.emobility.eu.org/SRA/Documents/eMobility_SRA_07_090115.pdf
- Energie Baden-Württemberg lays the groundwork for "smarter" energy consumption and generation. http://www-01.ibm.com/software/success/cssdb.nsf/CS/JSTS-7KZKLF?OpenDocument&Site=igbs&cty=en_us
- Energy Benchmarks TM47. CIBSE, 2008.
- Energy Efficiency Roadmap for India. Bureau of Energy Efficiency Government of India:
www.infraline.com/power/events/presentations/AjayMathur-BEE.pdf,
www.glassisgreen.com/papers/ECBC%20Mumbai/9th%20April,2009.pdf
- Energy Efficiency Technology Road Map from Bonneville Power Administration, July 2006.
www.bpa.gov/corporate/business/innovation/docs/2006/RM-06_EnergyEfficiency-Final.pdf
- Energy Efficient Buildings European Initiative. www.e2b-jti.eu
- Erdogan, Bilge; Abbott, Carl; Aouad, Ghassan. FUTURE GENERATION OF IT: ICT Vision Planning Workshop Report. University of Salford, Manchester, UK. 26th January 2009.
fiatech.org/tech-tools/industry-research/329-ict-vision-planning-workshop-report.html
- European Commission, DG Information Society and Media, Unit H4 "ICT for Sustainable Growth". ec.europa.eu/ictforsg,
ec.europa.eu/information_society/activities/sustainable_growth/energy_efficiency
- European Commission. Impacts of Information and Communication Technologies on Energy Efficiency. Final report. September 2008.
cordis.europa.eu/fp7/ict/sustainable-growth/studies_en.html,
ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/sustainable-growth/ict4ee-final-report_en.pdf
- European Technology Platforms. cordis.europa.eu/technology-platforms
- FIATECH. Capital Projects Technology Roadmap.
fiatech.org/tech-roadmap/overview.html
- Fischer, Martin and Kam, Calvin. PM4D Final Report. CIFE Technical Report Number 143. October 2002. cic.vtt.fi/vera/Documents/PM4D_Final_Report.pdf
- FP7 NMP Workprogramme 2010 – draft. February 19th 2009.

- Future Scenarios – ICT Enabled Environmentally Smart Buildings, UK Centre for Economic and Environmental Development (UK CEED), 2006
- Gay, D., Levis, P., von Behren, R., Welsh, M., Brewer, E., & Culler, D. (2003). The nesc language: A holistic approach to networked embedded systems. In PLDI '03: Proceedings of the ACM SIGPLAN 2003 conference on Programming language design and implementation, vol. 38, (pp. 1-11). New York, NY, USA: ACM.
- Green Building XML (gbXML), www.gbxml.org
- Heras, Jose-Javier de las and Zarli, Alain. ICT for Energy Efficiency. Ad-hoc Advisory Group. Smart Buildings Consultation Group, Final Report. 30 September 2008.
- Hietanen 2006, Model View Definition (MDV), www.blis-project.org/IAI-MVD
- High performance commercial buildings – a technology roadmap. Office of Building Technology, State and Community Programs, U.S. Department of Energy. October 2000. www.eren.doe.gov/buildings/commercial_roadmap
- ICT for Energy Efficiency. DG-Information Society and Media. Ad-Hoc Advisory Group Report. Brussels, 24.10.2008. cordis.europa.eu/fp7/ict/sustainable-growth/key-docs_en.html
- ICT for Energy Efficiency: Efficiency: Consultation Groups Sectors Reports. October 2008. cordis.europa.eu/fp7/ict/sustainable-growth/key-docs_en.html
- IFD Library White Paper, 2008. www.ifd-library.org
- Indoor environments and human comfort, health and productivity. Technical University of Denmark. www.iciee.byg.dtu.dk
- Intellect: Case Study Digest (Transport, Buildings and Energy Supply), pg 10. <http://www.intellectuk.org/content/view/3785/84/>
- Intellect: IBM ICT-enabled office optimisation <http://www.intellectuk.org/content/view/3789/84/#IBM>
- IntUBE project, Intelligent Use of Buildings' Energy Information. 2009. www.intube.eu
- ITOBO project, Information and Communication Technology for Sustainable and Optimised Building Operation, zuse.ucc.ie/itobo
- Jackson, Ric. FIATECH's Capital Projects Technology Roadmap: how we can use it today. National Streamlining Conference. Washington, DC. February 15-16, 2006. www.natlpartnerstreamline.org/conference_ppts/jackson_roadmap_2_15.ppt
- JISC Advanced Display Technology. Paul Anderson. October 2005. <http://www.jisc.ac.uk/whatwedo/services/techwatch/reports/horizonsscanning/hs0503.aspx>
- LDAP, Lightweight Directory Access Protocol. Ask Yahoo! ask.yahoo.com/20000414.html
- Malatras, Apostolos; Asgari, Abolghasem (Hamid); Baugé, Timothy; Irons, Mark. An Enterprise Architecture for Integrating Building Services. The 1st International Conference on Industrialised, Integrated, Intelligent Construction. I3CON project. 14-16 May 2008. Pp. 119-129. http://www.i3con.org/files/conference-1/I3CON_2008_Conference_Proceedings.pdf
- ManuBuild. www.manubuild.org
- Martin LaMonica “Smart' device makers: Variable electricity rates needed”, CNET's Green Tech blog, December 14, 2009, news.cnet.com/8301-11128_3-10414993-54.html
- Métral, Claudine; Falquet, Gilles; Vonlanthen, Mathieu. An Ontology-based System for Urban Planning Communication. In: Teller, Jacques; Lee, John R.; Roussey, Catherine (Eds.): Ontologies for Urban Development. Studies in Computational Intelligence Vol. 61 Springer 2007, ISBN 978-3-540-71975-5. www.informatik.uni-trier.de/~ley/db/series/sci/sci61.html

- MTP Dynamic Demand Case Study. <http://www.intellectuk.org/content/view/3789/84/>
- National Action Plan for Energy Efficiency, Vision for 2025: A Framework for Change. U.S. Environmental Protection Agency. November 2008. www.epa.gov/eeactionplan
- NESSI Strategic Research Agenda. Volumen 3.2. Revision 2.0. May 2009. [www.nessi-europe.eu/Nessi/Portals/0/Nessi-Repository/SRA/Documents/NESSI_SRA_Vol3_2_update_20090510_public\[1\].pdf](http://www.nessi-europe.eu/Nessi/Portals/0/Nessi-Repository/SRA/Documents/NESSI_SRA_Vol3_2_update_20090510_public[1].pdf)
- New Collaborative Working Environments 2020. Report on industry-led FP7 consultations and 3rd Report of the Experts Group on Collaboration@Work. European Commission, Information Society and Media Directorate-General, Emerging Technologies and Infrastructures, New Working Environments. February 2006. ec.europa.eu/information_society/activities/atwork/hot_news/publications/documents/new_collab_environments_2020.pdf
- Noguchi, Masa. The 'Mass Custom Design' Approach to the Delivery of Quality Affordable Homes. www.masscustomhome.com
- NOKIA Smart home solutions. smarthomepartnering.com
- O'Donnell, J., Morrissey, E., Keane, M., and Bazjanac, V. 2004, BuildingPI: A future tool for building life cycle analysis, SimBuild, Boulder, Co August 4-6, United States.
- OKSMAN Vladimir, GALLI Stefano. G.hn: The New ITU-T Home Networking Standard in IEEE Communications Magazine, October 2009
- Paiho, Satu; Ahlqvist, Toni; Piira, Kalevi; Porkka, Janne; Siltanen, Pekka; Tuomaala, Pekka & Kiviniemi, Arto. Roadmap for ICT based Opportunities in the Development of the Built Environment. VTT. 2008. www.vtt.fi/inf/pdf/tiedotteet/2008/T2444.pdf
- Powell, Kevin. Energy Smart Buildings. U.S. General Services Administration. 22 June 2008. [www.midatlanticv6tf.org:8080/kb/Members/digitaldivide/green-protocol-wg/Final - Knowledge Paper Energy smart buildings KP.doc](http://www.midatlanticv6tf.org:8080/kb/Members/digitaldivide/green-protocol-wg/Final_Knowledge_Paper_Energy_smart_buildings_KP.doc)
- Renewable Heating & Cooling - European Technology Platform. Being established in 2009. www.aebiom.org (a dedicated website for the RHC-ETP is under development).
- Research Priorities for the Definition of a Multi-Annual Roadmap and Longer Term Strategy. Ad-hoc Industrial Advisory Group, 28 December 2009. Energy-efficient Buildings PPP (EeB), www.e2b-ei.eu
- Richards, Darren. Roundup of technologies for off-site construction. Construction Industry Federation. www.cif.ie/asp/section.asp?pm=print&s=764. 13 April 2009.
- ROADCON, Strategic Roadmap towards Knowledge-Driven Sustainable Construction. 2003. cic.vtt.fi/projects/roadcon
- Roadmap for a transformation of energy efficiency in buildings. wbcsd.3xscreen.co.uk/wbcsd-eeb.html
- Roadmap of the European Technology Platform for Advanced Engineering Materials and Technologies (EUMAT). June 2006. www.eumat.org/
- Sanguinetti, Paola; Eastman, Charles; Augenbroe, Godfried. Courthouse Energy Evaluation: BIM and Simulation Model Interoperability In Concept Design. Building simulation 2009, Eleventh International IBPSA Conference. Glasgow, Scotland, 27-30 July 2009. www.ibpsa.org/m_bs2009.asp
- Schulte, W.; Pezzini, Massimo; Sholler, Daniel; & Natis, Yefim V. Gartner: Smart Devices and Sense-and-Respond Systems Are Event-Driven. 12 October 2009.

- Service-oriented architecture (SOA) definition. www.service-architecture.com/web-services/articles/service-oriented_architecture_soa_definition.html
- Sinipoli, Jan. Using Structured Cable Solutions for BAS. October 2008. www.automatedbuildings.com/news/oct08/articles/sinopoli/080930100202sinopoli.htm
- SMART 2020: Enabling the low carbon economy in the information age. The Climate Group. Global e-Sustainability Initiative (GeSI). 2008. gesi.org/
- Smart Buildings, www.automatedbuildings.com/news/jan06/articles/labella/labella.htm
- SmartGrids Strategic Deployment Document for Europe's Electricity Networks of the Future, SmartGrids Technology Platform, Draft, September 2008. www.smartgrids.eu
- SmartHouse/SmartGrid project. D1.2 Technology Trends for SmartHouse/SmartGrid. 2 February 2009. www.smarthouse-smartgrid.eu
- Stockholm Environment Institute, A European Eco-efficient Economy, 23–25 July 2009. NO working web-link to REPORT itself at the present, www.euractiv.com/en/energy-efficiency/sweden-seeks-steer-eu-energy-efficient-path/article-183378
- Strategic Research Agenda & Strategy Deployment Document. European Biofuels Technology Platform (EBFTP). January 2008. www.biofuelstp.eu/
- Strategic Research Agenda “Networked and Electronic Media” (NEM) European Technology Platform. September 2009. www.nem-initiative.org/Documents/NEM-SRA-070a.pdf
- Strategic Research Agenda for the European Construction Sector. December 23rd , 2005. European Construction Technology Platform (ECTP). www.ectp.org
- Strategic Research Agenda, European Photovoltaic Technology Platform. June 2007. www.eupvplatform.org
- Strategic Research Agenda, European Steel Technology Platform (ESTEP). April 2005. cordis.europa.eu/estep/
- Strategic Research Agenda, European Technology Platform for Electricity Networks of the Future (SmartGrids). 2007. www.smartgrids.eu
- Strategic Research Agenda, European Technology Platform for Sustainable Chemistry (SusChem). 2005. www.suschem.org
- Strategic Research Agenda, European Technology Platform for Wind Energy (TPWind). July 2008. www.windplatform.eu
- Strategic Research Agenda, European Technology Platform on Smart Systems Integration (EPoSS). August 8th, 2006. <http://www.smart-systems-integration.org>
- Strategic Research Agenda, Forest-Based Sector Technology Platform (FTP). January 2006. www.forestplatform.org/
- Strategic Research Agenda, Networked and Electronic Media European Technology Platform (NEM). September 2008. www.nem-initiative.org
- Strategic Research Agenda, Photonic21 European Technology Platform. April 2006. www.photonics21.org
- Strategic Research Agenda. ECTP Focus Area 7: Processes and ICT. 2008. www.ectp.org/groupes2/params/ectp/download_files/Doc335v1_grp27.pdf
- Strategic Research Agenda. European Construction Technology Platform (ECTP). December 2005. www.ectp.org/

- Strategic Research Agenda. European Hydrogen and Fuel Cell Technology Platform (HFP). July 2005. www.hfpeurope.org/
- Strategic Research Agenda. European Solar Thermal Technology Platform (ESTTP). December 2008. esttp.org/
- Strategic Research Agenda. ManuFuture Platform. November 2004. www.manufuture.org/
- Strategic Research Agenda. Mobile and Wireless Communications Technology Platform (eMOBILITY). August 2006. www.emobility.eu.org/
- Strategic Research Agenda. Networked European Software & Services Initiative (NESS). July 2006. www.nessi-europe.com
- Susan L. Epstein, “Metaknowledge for Autonomous Systems” DCS, Hunter College, City University of New York, USA. 4c.ucc.ie/web/upload/publications/inProc/SS604Eps.pdf
- Technology Roadmap for Intelligent Buildings – CABA 2002. www.caba.org/Content/Documents/Document.ashx?DocId=24179
- The building and construction industry technology roadmap. CWIC project – Collaborative Working in Construction. Revision 4. November 2005. www.cwic.org.au/reportsR.html
- The Climate Group. SMART 2020: Enabling the low carbon economy in the information age. www.theclimategroup.org/assets/resources/publications/Smart2020Report.pdf
- The Sustainability Potential of Cloud Computing: Smarter Design. www.environmentalleader.com/2009/07/20/the-sustainability-potential-of-cloud-computing-smarter-design/
- The Unified Physical Infrastructure Approach. White paper. Panduit. August 2009. www.panduit.com/LandingPages/UPIVision/index.htm
- U.S. Department of Energy. Building technologies program, Commissioning. www1.eere.energy.gov/buildings/commercial/commissioning.html
- U.S. Green Building Council (USGBC). Roadmap to sustainable government buildings. 2009. www.usgbc.org/ShowFile.aspx?DocumentID=5486
- U.S. Green Building Council: LEED. www.usgbc.org
- UBC Agenda 21, Action Programme 2004-2009 - Roadmap for Sustainable Baltic Cities. VII General Conference of the Union of the Baltic Cities, Klaipeda, 17-18 October 2003. www.ubc.net/plik,429.html
- UK NTP Construction Roadmap and Scoping Studies. nationalplatform.constructingexcellence.org.uk/publications.jsp
- Using Financial and Market-based Mechanisms to improve Building Energy Efficiency in China. www.camcoglobal.com/reeep/index.htm, www.camcoglobal.com/reeep/Final_report_090324_en.pdf
- Virtanen, Markku (ed.). Towards net-zero primary energy use & carbon emissions in buildings & communities. Strategic plan 2007-2012. IEA Energy Conversation in Buildings & Community Systems Programme (ECBCS). 2008. www.ecbcs.org/docs/ECBCS_Strategic_Plan_2007-2012.pdf
- Vision 2020. ManuFuture Platform. November 2004. www.manufuture.org/
- Vision and Strategic Research Agenda. Focus Area Processes and ICT. May 19th, 2008 European Construction Technology Platform (ECTP). www.ectp.org
- Wix 2006, Information Delivery Manual (IDM), ISO 29481-1, idm.buildingsmart.no

- World Business Council for Sustainable Development: Energy Efficiency in Buildings – Transforming the Market – June 2009
www.wbcd.org/DocRoot/WvNIJhLQBmCIKuj0eN0h/91719_EEBReport_WEB.pdf
- Yick, Jennifer; Mukherjee, Biswanath; Ghosal, Dipak: Wireless sensor network survey. *Computer Networks* 52(12): 2292-2330 (2008)
- ZARLI, Alain. Towards an ICT infrastructure for Energy Positive Neighbourhood. European Large Scale Actions (ELSA): Thematic Working Group on ICT for Energy Efficiency. Brussels, 8th of October 2009.

Note: Detailed results from the REEB project are accessible through the downloads sections of <http://www.ict-reeb.eu/> and along with possible subsequent updates will be available through <http://www.ict4e2b.eu/>.

These results include, but are not limited to:

- Criteria and selection of best practice-case studies (consisting of 80+ collected case studies)
- Best practices guide (consisting of 12 best practices)
- Selection and categorization criteria, and mapping of research on energy efficiency (consisting of a detailed analysis of 50+ projects)
- Detailed vision for ICT enabled energy efficiency in buildings and analysis of related activities.
- Detailed roadmap describing research actions at sub-category level
- Implementation recommendations (including 60+ research topics and ideas from relevant stakeholders)
- Lecture notes on energy efficiency in building construction (containing lecture module descriptions and lecture notes)

Abbreviations

6LoWPAN.....	IPv6 (internet protocol version 6) over low power wireless area networks
A/V	Audio/Visual
API	Application Programming Interface
BAC.....	Building Automation and Control
BACNet.....	Communication protocol for building automation and control.
BACS	Building Automation and Control System
BEM	Building Energy Management
BEMS	Building Energy Management System
BIM	Building Information Model/-ling
BMS	Building Management Systems
BREEAM	Building Research Establishment Assessment Method (UK)
buildingSMART...	International Alliance for Interoperability in the Building and Construction domain (previously known as IAI)
CAD	Computer Aided Design
CAE.....	Computer Aided Engineering
CASBEE.....	Comprehensive Assessment System for Building Environmental Efficiency (green building standard, Japan)
CO ₂	Carbon dioxide
DDC	Direct Digital Control
DEM.....	District Energy Management System
DGNB.....	Deutsche Gesellschaft für Nachhaltiges Bauen e.V. (German Sustainable Building Council)
E2B.....	Energy Efficient Buildings initiative
EACI.....	Executive Agency for Competitiveness and Innovation
ECMS	Energy Control Management Systems
EE	Energy Efficiency
EEB.....	Energy Efficient Buildings
EnOcean	Wireless energy harvesting technology used primarily in building automation systems
EPBD.....	Energy Performance of Buildings Directive
ESCO.....	Energy Saving Company
EU.....	European Union
HomePlug.....	Alliance to promote and standardize networking over power lines
HQE.....	Haute Qualité Environnementale (green building standard, France)
HVAC.....	Heating, Ventilation and Air Conditioning
ICT	Information and Communication Technology
ICT4EEB.....	ICT for Energy Efficient Buildings
IDE	Integrated Development Environment

IFC	Industry Foundation Classes (interoperability standard defined by buildingSMART)
IIC	Intelligent & Integrated Control (one of the 5 main categories for RTD identified by REEB)
IPR	Intellectual Property Right
IT	Information Technology
J2ME	Java platform for mobile devices and embedded systems
KNX	OSI-based network communications protocol for intelligent buildings
KPI	Key Performance Indicator
LEED	Leadership in Energy & Environmental Design (green building certification system, USA)
LonWorks.....	Networking platform to address the needs of control applications
MCC.....	Main Classification Category for RTD identified by REEB
MINERGIE	Mehr Lebensqualität, tiefer Energieverbrauch (green building standard, Switzerland)
OGEMA.....	Open Gateway Energy Management Alliance
OS	Operating System
PC.....	Personal Computer
PLC	Power Line Communication
PPP	Public-Private Partnership
QoS	Quality of Service
RES	Renewable Energy Sources
RFID	Radio Frequency Identifier
ROI.....	Return of Investment
RTD.....	Research and Technology Development
SBA	Sustainable Building Alliance
SI.....	Sensing Infrastructure
SME	Small or Medium Size Enterprise
TCO.....	Total Cost of Ownership
TCP/IP.....	Transmission Control Protocol / Internet Protocol
TV	Television
W3C	World Wide Web Consortium
Wi-Fi	Wireless Fidelity (IEEE 802.11b wireless networking)
WSN.....	Wireless Sensor Network
X10.....	Technology for lighting and small appliance control in home automation
ZigBee.....	Standard for wireless personal area networks



ICT Supported Energy Efficiency in Construction

Strategic Research Roadmap and Implementation Recommendations

Most energy usage of buildings throughout their life cycle is during the operational stage (~80%). The decisions made in the conception and design stages of new buildings, as well as in renovation stages of existing buildings, influence about 80% of the total life cycle energy consumption. The impact of user behaviour and real-time control is in the range of 20%. ICT has been identified as one possible means to design, optimize, regulate and control energy use within existing and future (smart) buildings.



This book presents a collection of best practices, gap analysis of current research and technology development activities, a research roadmap, and a series of recommendations for ICT supported energy efficiency in buildings. Key research, technology, and development priorities include: integrated design and production management; intelligent and integrated control; user awareness and decision support; energy management and trading; integration Technologies.



The vision for ICT supported energy efficiency of buildings in the short, medium, and long term is advocated as follows:

- Short term:** Buildings meet the energy efficiency requirements of regulations and users
- Medium term:** The energy performance of buildings is optimised considering the whole life cycle
- Long term:** New business models are driven by energy efficient “prosumer” buildings at district level – long term.



ISBN 978-951-38-7432-2

