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

# Deliverable D1.1: Classified Research Areas

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SEVENTH FRAMEWORK PROGRAMME

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# 1 Introduction

This document is a re-submission of deliverable D1.1 “Classified Research Areas” (due at M2, October, 2010) requested by the project final review. It was revised according to the review comments by the whole consortium and by two experts.

## 1.1 Purpose of this Document

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 for action management which will drastically change our future built environment.

ICT is recognised as key for empowering people with both smart e-metering and new smart 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 integrated with information management for an optimal energy flow over its lifecycle. 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.

This idea, focused in the improvement of energy-efficiency through innovative ICT, leading to the so-called "smart buildings" of tomorrow as a key challenge in our future world, is the same promoted idea of REEB project, a project involved in ICT supporting energy efficiency strategies in the building sector, on which ICT 4 E2B Forum is based.

The REEB project, in relation to the current challenge on the future RTD (Research & Technological Development) in ICT support to E2B, provides the first Coordination Action (CA) roadmap that has been developed in this area, and delivers the first outcomes, based on a preliminary building-up of the communities.
This roadmap outlines RTD priorities in short, medium and long term within the domain on ICT enabled energy efficient buildings. These are organised into 5 main categories. The 4 first ones are application domain oriented and the 5$^{th}$ one is cross-cutting (see Figure 1):

- Tools for integrated design and production;
- Intelligent & Integrated Control;
- User awareness & decision support;
- Energy management & trading;
- Integration technologies.

With reference to this scenario ICT4E2B Forum intends to promote, through community building activities, a better understanding, a closer dialogue and a more active cooperation between researchers, end-users/practitioners, building owners, technology-suppliers, and software developers as regards the use of ICT to support informed decision-making (both human and automated) in the current delivery and use of sustainable and energy-efficient buildings and emerging broader district or Smart Cities.

In order to provide a continuous up-to-date of the REEB roadmap this deliverable aims at the identification, definition and classification of key research topics and related new knowledge emerging from the identified Priority Areas of REEB CA. In the rest of this document we do therefore take as baseline the final version of REEB classification exposed in the "D4.1 Vision..."[1] of the REEB "coordination action" project.

This improvement work is done by considering:

- The identification of the new possible areas of interest for research and technological activities because there is a need to check against all the scientific works and RTD activities in ICT support to E2B so far achieved or ongoing. This activity is done in two different steps:
    - A preliminary analysis of the current scientific literature (to be further addressed in D1.2);
    - A preliminary analysis of the current RTD activities at European level (to be further addressed in D1.3).
- The review and assessment of the REEB classification aimed at better define the different research topics, based bringing together the contributions provided by the project partners and the research topics retrieved in the previous step.

In order to assess how ICT support Energy Efficiency in Smart Cities the reference system, i.e. the "starting point" used as basis of the performed analysis, is represented by the model developed by the European Smart Cities project[2]. The 6 smart city areas have been further elaborated, in accordance with IREEN project, in 5 application areas and sub-areas to define the concept of energy efficient Smart City system.
In order to envision the extension of the scope of ICT4E2B project from buildings towards Smart City system, it is useful to evaluate the intersection of the identified Smart City system application areas and the ICT key research topics; in the document we provide some concrete example of this procedure.

The result of this deliverable acts as baseline for the activities to be performed during the following of the project, and also for the development of IREEN Research Roadmap (ICT Roadmap for Energy Efficient Neighbourhoods) in order to guarantee the necessary interweaving and interoperability between the targeted domains of the two projects, i.e. buildings and districts. The scientific and technological analysis of Workpackage 1 and the road-mapping exercise of Workpackage 2 are performed against the key research topics identified and detailed in this report.

[1] http://www.ict-reeb.eu/objects2/REEB_D41_Vision_m19_released.pdf
[2] "Smart cities - Ranking of European medium-sized cities", Smart Cities project (www.smart-cities.eu), October 2007. URL: http://www.smart-cities.eu/download/smart_cities_final_report.pdf

## 1.2 Document Structure

The present document is structured as follows:

- Chapter 2 gives an overview about the current scientific literature and the current RTD activities at European Level.
- Chapter 3 contains a review of REEB areas, involving an accurate definition and explanation of each topic, taking into account the findings of the previous overview analysis.
- Chapter 4 envisions the extension of ICT4E2B Forum scope towards Smart City systems by re-elaborating the Smart City model in 5 application areas and sub-areas, and by providing some concrete examples of application of ICT key research topics to the identified Smart City system areas.

## 1.3 Contributions of Partners

D'Appolonia has had the main responsibility to prepare this document. Preparation of update of REEB classification has been divided between partners as follows:

1. Tools for EE Design and Production Management by D'Appolonia
2. Intelligent & Integrated Control by Schneider
3. User awareness and decision support by MOSTOSTAL
4. Energy Management & Trading by SAP
5. Integration technologies by ATOS

Also the application of ICT key research topics to the 5 application areas, useful to define the concept of energy efficient Smart City system, and performed in Chapter 4, has been divided following the scheme described above.

# 2 Identification of the New Research Areas in ICT Support to Energy Efficiency in Buildings

## 2.1 Scientific Literature Overview

The first stage of our work on updating REEB research topics classification has been done by addressing the current scientific activities related to Energy Efficient Buildings and in particular its ICT related work.

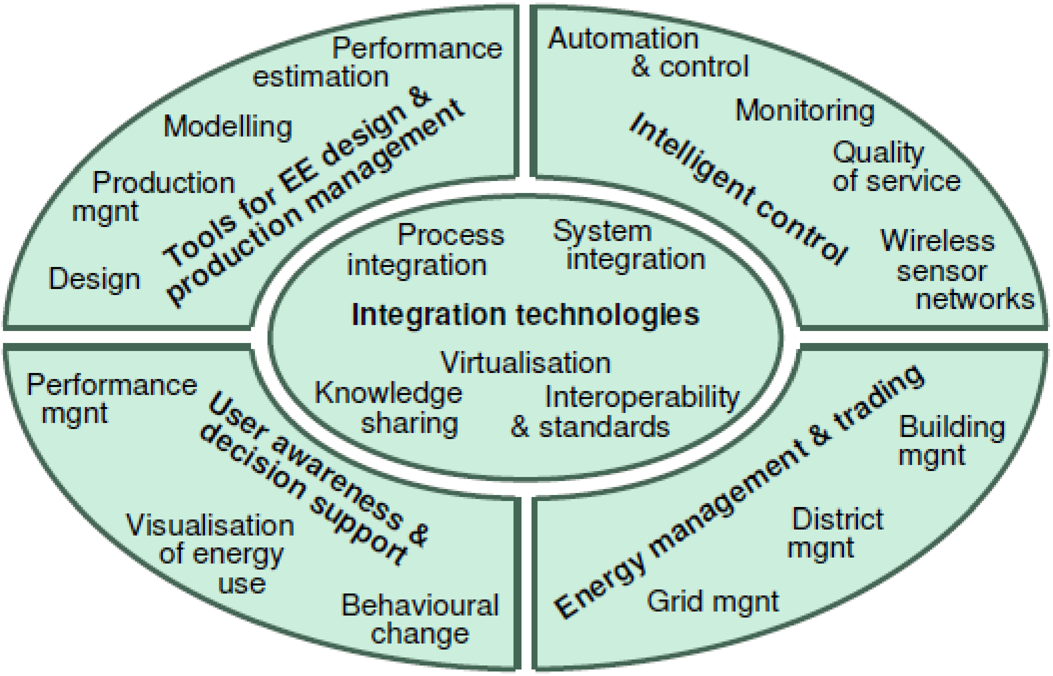


**Figure 1: REEB Classification with Subcategories**

This exploration of the relevant scientific literature has been based on the study of the scientific literature database, retrieving and analysing relevant articles and scientific information sources. Based on a survey of relevant datasources we have used as information source the **Elsevier Compendex Database**, which is the most comprehensive bibliographic database of scientific and technical engineering research available, covering all engineering disciplines. In fact it includes millions of bibliographic citations and abstracts from thousands of engineering journals and conference proceedings; when combined with the Engineering Index Backfile (1884-1969), Compendex covers well over 120 years of core engineering and scientific literature.

Our first aim has been to address the whole energy efficient buildings research framework, trying, through a top-down approach, to detail the role of ICT research topics inside this larger context.

To cover this large domain by querying the literature database, we based our queries text on the very general keywords “energy”, “efficient” and “building”, and took into account their semantic families by the use of natural language processing algorithms. The subsequent analysis has been therefore achieved on this bulk of possible relevant papers, focusing our attention to the publications from 2009, since we are mostly interested on the current state of the art and its influence on ICT for Energy Efficiency research classification

Within this bulk of 1835 scientific publications we addressed the core interest of our analysis, i.e. the review and identification of the different research topics related to ICT for EE Buildings, we have been able to identify through a systematic keyword analysis, 2802 different research keywords able to address the different publication topics.

Among this 2802 keywords we have been able to select 291 keywords (about the 10%) that are in principle related to ICT and can be easily positioned inside the 5 main categories, that therefore results as still relevant for the broad classification of research topics on ICT for EE Buildings.

We have been able however to identify some terms that at first analysis don't seem to be clearly considered inside REEB classification, neither directly or by synonyms. Namely:

- Tools for EE design and production management
    - No new terms
- Intelligent control
    - Decision trees
- User awareness and decision support
    - Data Mining
- Energy management and trading
    - No new terms
- Integration technologies
    - Cloud Computing
    - Software Agents

The result of this analysis (the detailed analysis process mentioned before will be provided in D1.2) underlines how the REEB classification, that has been the first CA in this area, can still act as baseline for any analysis of this research areas. However the results show that there is still the need to better analyse and address the contexts related to the different scientific areas.

## 2.2 European Research Activities on ICT for Energy Efficiency in Buildings

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.

In this section an overview on European Research projects related to ICT impact in EEBs is presented. This work has been done with the aim of making a preliminary matching between the current RTD activities carried out at European level and the REEB Classification and its subcategories as show in Figure 1.

This matching allowed to understand the level of actuality of the REEB classification with respect to European RTD projects, while further investigations will be done starting from this preliminary overview in Task 1.3, and they will result in Deliverable 1.3.

With reference to the RTD projects, considering the ICT4E2B domain (ICT-2007.6.3, ICT-2009.6.3, ICT-2010.10.2, ARTEMIS-2008-1) inside FP7 and CIP 47 projects were accounted.

### 2.2.1 Related Projects in FP7 and CIP Program

The projects are listed in Table 1 below.

**Table 1: Related Projects in FP7 and CIP Program**

| Project name | Program | Start & End Date | Description | Website | Mapping to REEB Classification |
|---|---|---|---|---|---|
| 3e-Houses | CIP ICT PSP | 2010-02-01 2013-01-31 | Energy Efficient e-Houses | http://www.3ehouses.eu | Energy management and trading |
| AIM | FP7 | 2008-06-01 2010-05-31 | A novel architecture for modelling, virtualising and managing the energy consumption of household appliances | http://www.ict-aim.eu | Tool for EE design and production management, intelligent control |
| BeAWARE | FP7 | 2008-05-01 2011-04-30 | Boosting energy awareness with adaptive real-time environments | http://www.energyawareness.eu/beaware | Intelligent control, user awareness and decision support |
| BEST Energy | CIP ICT PSP | | Built Environment Sustainability and Technology in Energy | http://www.bestenergyproject.eu | Intelligent control, user awareness and decision support |
| BeyWatch | FP7 ICT | 2008-12-01 2011-05-31 | Building EnergY WATCHer | http://www.beywatch.eu/ | Intelligent control, user awareness and decision support |
| CLEAR-UP | FP7 NMP | 2008-11-01 2012-10-31 | Clean buildings along with resource efficiency enhancement using appropriate materials and technology | http://www.clear-up.eu | Integration technologies |
| CLIMAWIN | FP7 SME | 2010-10-01 2012-09-30 | An intelligent window for optimal ventilation and minimum thermal loss | http://www.climawin.aau.dk | Intelligent control |
| COST-EFFECTIVE | FP7 NMP | 2008-10-01 2012-09-30 | Resource - and cost - effective integration of renewable in existing high-rise buildings | http://www.cost-effective-renewables.eu/ | Integration technologies |
| DEHEMS | FP7 | 2008-06-01 2010-11-30 | Digital environment home energy management system intelligent meters, real time | http://www.dehems.eu | Tool for EE design and production management, intelligent control |
| E3SoHo | CIP ICT PSP | 2010-02-01 2013-01-31 | ICT services for Energy Efficiency in European Social Housing | http://www.e3soho.eu/ | Intelligent control, user awareness and decision support |
| E4U | FP7 ICT | 2008-06-01 2009-11-30 | Electronics enabling efficient energy usage | http://www.e4efficiency.eu | Intelligent control |
| ECO-LIFE | FP7 Energy | 2010-01-01 2015-12-31 | Sustainable Zero Carbon ECO-Town Developments Improving Quality of Life across EU | http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=1&CAT=PROJ&QUERY=012a4 | Energy management and trading |

| | | | | | |
|---|---|---|---|---|---|
| | | | | 6cbefcc:fea4:21143ef0&RCN=94492 | |
| eDIANA | CIP ICT PSP | 2009-02-10<br>2012-01-31 | Embedded Systems for Energy Efficient Buildings | http://www.artemis-ediana.eu/ | Integration technologies |
| E-Hub | FP7 NMP | 2010-12-01<br>2014-11-30 | Energy-Hub for residential and commercial districts and transport | http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=1&CAT=PROJ&QUERY=012d33078f73:df3f:21da0c7c&RCN=97061 | Energy management and trading |
| ENERGY WARDEN | FP7 ICT | 2010-01-01<br>2012-12-31 | Design and real time energy sourcing decisions in buildings | http://www.energywarden.net | Tool for EE design and production management, intelligent control, energy management and trading |
| EnerSIP | FP7 ICT | 2010-01-01<br>2012-05-31 | Energy Saving Information Platform for Generation and Consumption Networks | http://www.enersip-project.eu | Energy management and trading, integration technologies |
| EnPROVE | FP7 ICT | 2010-02-01<br>2013-01-31 | Energy consumption prediction with building usage measurements for software-based decision support | http://enprove.eu/ | Tool for EE design and production management, integration technologies |
| EnRiMa | FP7 ICT | 2010-10-01<br>2014-03-31 | Energy Efficiency and Risk Management in Public Buildings | http://www.enrima-project.com | User awareness and decision support |
| eSESH | CIP ICT PSP | 2010-03-01<br>n. a. | Saving Energy in Social Housing with ICT | http://www.esesh.eu/ | Integration technologies |
| FIEMSER | FP7 ICT | 2010-02-01<br>2013-01-31 | Friendly Intelligent Energy Management System for Existing Residential Buildings | http://www.fiemser.eu/ | Energy management and trading |
| GENESIs | FP7 ICT | 2010-04-01<br>2013-03-31 | Green sEnsor NEtworks for Structural monItoring | http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=2&CAT=PROJ&QUERY=012d330807a0:9404:310ef3c1&RCN=95046 | Intelligent control |
| GREENERBUILDINGS | FP7 ICT | 2010-09-01<br>2013-08-31 | An ubiquitous embedded systems framework for energy-aware buildings using activity and context knowledge | http://www.greenerbuildings.eu/ | Integration technologies |
| H2SUSBUILD | FP7 NMP | 2008-10-01<br>2012-09-30 | Development of a clean and energy self-sustained building in the vision of integrating H2 economy with renewable energy sources | http://www.h2susbuild.ntua.gr/ | Energy management and trading |
| HESMOS | FP7 ICT | 2010-09-01<br>2013-08-31 | ICT Platform for Holistic Energy Efficiency Simulation and Lifecycle Management Of | http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_E | Tool for EE design and production management, integration |

| | | | | | |
|---|---|---|---|---|---|
| | | | Public Use Facilities | N&ACTION=D&DOC=1&CAT=PROJ&QUERY=012d330869b2:ed0e:6e46108f&RCN=95500 | technologies |
| H-KNOW | FP7 NMP | 2009-01-01 2011-12-31 | Advanced infrastructure for knowledge based services for buildings restoring | http://www.h-know.eu/ | User awareness and decision support |
| HOBNET | FP7 ICT | 2010-06-01 2013-05-31 | Holistic Platform Design for Smart Buildings of the Future Internet | http://www.hobnet-project.eu/ | Energy management and trading |
| HosPilot | CIP ICT PSP | 2009-03-01 2012-02-29 | Efficient energy efficiency control in hospitals | http://www.hospilot.eu/ | Intelligent control |
| ICT 4 E2B FORUM | FP7 ICT | 2010-09-01 2012-10-31 | 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 | http://www.ict4e2b.eu | |
| INTUBE | FP7 ICT | 2008-05-01 2011-04-30 | Intelligent use of buildings' energy information | http://www.intube.eu/ | User awareness and decision support, integration technologies |
| LITES | CIP ICT PSP | 2009-12-01 2012-05-31 | Intelligent street lighting for energy saving | http://www.lites-project.eu/ | Intelligent control |
| MESSIB | FP7 NMP | 2009-03-01 2013-02-28 | Multi-source energy storage system integrated in buildings | http://www.messib.eu/ | Intelligent control, integration technologies |
| MOBI3CON | FP7 SME | 2009-01-01 2011-06-30 | Developing mobile 3d data collect-ion, processing and dissemination solution for construction SME-s | http://mobi3con.eii.ee | Integration technologies |
| NOBEL | FP7 ICT | 2010-02-01 2012-07-31 | Neighbourhood Oriented Brokerage Electricity and monitoring system | http://www.ict-nobel.eu/ | Energy management and trading |
| PEBBLE | FP7 ICT | 2010-01-01 2012-12-31 | Positive Energy Buildings thru Better controL dEcisions | http://www.pebble-fp7.eu/ | Energy management and trading |
| PICODICON | FP7 SME | 2009-08-01 2011-07-31 | Development of a mobile Pico-projector based data Displaying solution for Construction SMEs enabling the paperless construction site | http://www.picodicon.com/ | Integration technologies |
| PIME'S | FP7 Energy | 2009-12-01 2014-11-30 | CONCERTO communities towards optimal thermal and electrical efficiency of buildings and districts, based on MICROGRIDS | http://www.pimes.eu/ | Intelligent control |
| POBICOS | FP7 ICT | 2008-05-01 2011-04-30 | Platform for Opportunistic Behaviour in Incompletely Specified, Heterogeneous Object Communities | http://www.ict-pobicos.eu/ | User awareness and decision support |

| | | | | | |
|---|---|---|---|---|---|
| PRESTO | FP7 SME | 2008-02-01<br>2010-01-31 | Identification of priority research topics for SME associations in the construction sector with a focus on new technologies in the Energy, ICT and New Materials domains | http://www.presto-project.eu/ | Integration technologies |
| REEB | FP7 ICT | 2008-05-01<br>201-04-30 | The European strategic research roadmap to ICT enabled energy-efficiency in buildings and construction | http://www.ict-reeb.eu | |
| REViSITE | FP7 ICT | 2010-02-01<br>2012-0131 | Roadmap Enabling Vision and Strategy for ICT-enabled Energy Efficiency | http://www.revisite.eu/ | User awareness and decision support |
| SAVE ENERGY | CIP ICT PSP | 2009-03-01<br>2011-08-31 | Save Energy | http://www.ict4saveenergy.eu/ | Intelligent control |
| SEEMPUBS | FP7 NMP-ENV-ICT-ENERGY | 2010-09-01<br>2013-08-31 | Smart Energy Efficient Middleware for Public Spaces | http://seempubs.polito.it/ | Integration technologies |
| SmartCoDe | FP7 ICT | 2010-01-01<br>2012-12-31 | Smart Control of Demand for Consumption and Supply to enable balanced, energy-positive buildings and neighbourhoods | https://www.fp7-smartcode.eu/ | Energy management and trading |
| SMARTHOUSE/SMARTGRID | FP7 ICT | 2008-09-01<br>2011-02-28 | Smart houses interacting with smart grids to achieve next-generation energy efficiency and sustainability | http://www.smarthouse-smartgrid.eu/ | Integration technologies |
| SPORTE2 | FP7 ICT | 2010-09-01<br>2013-08-31 | Intelligent Management System to integrate and control energy generation, consumption and exchange for European Sport and Recreation Buildings | http://www.sporte2.eu/ | Energy management and trading |
| TIBUCON | FP7 ICT | 2010-09-01<br>2013-08-31 | Self Powered Wireless Sensor Network for HVAC System Energy Improvement - Towards Integral | http://tibucon.eu/index.html | Intelligent control |
| V-CITY | FP7 ICT | 2008-12-01<br>2011-11-30 | The virtual city | http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=1&CAT=PROJ&QUERY=012d3308dfc8:c0a4:5255cfc1&RCN=89240 | Integration technologies |

### 2.2.2 Findings

This classification work allows to clearly underline the actuality of REEB classification with respect to the on-going RTD activities, considering that the projects cover most of the terms of REEB classification. Figure 2 shows the distribution of research projects among different REEB priority areas. The predominant area is “Intelligent Control”, consistent also with REEB project finding; this result will be further investigated in Deliverable 1.3.

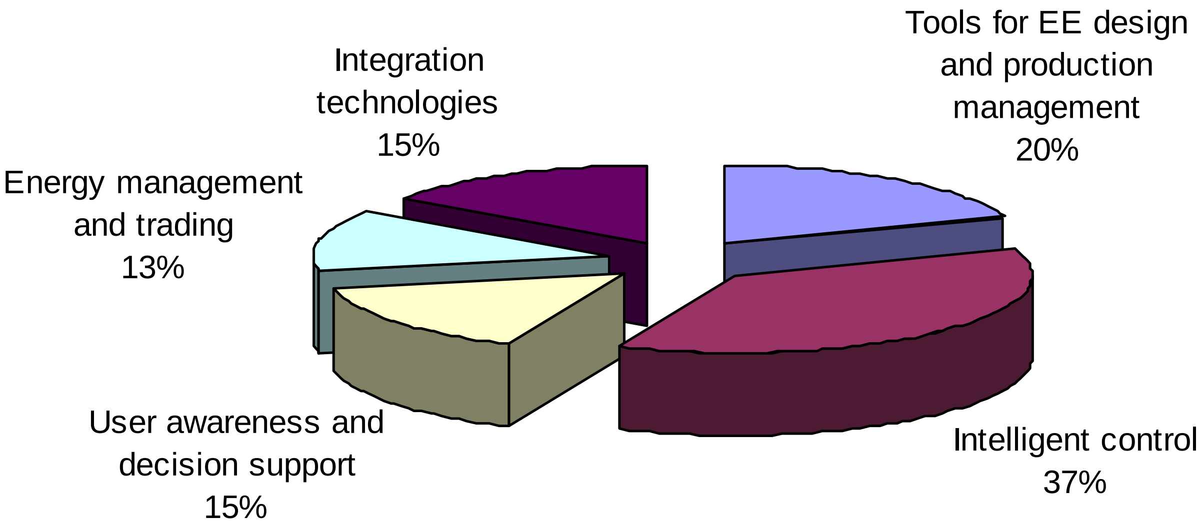


**Figure 2: Distribution of Research Projects among the Different REEB Priority Areas**

# 3 Updated REEB Classification of Research Areas

In this section we provide an updated version of the REEB classification of the ICT for Energy Efficiency in Buildings by using as baseline the REEB classification, enriching and further clarifying the different topics, by introducing a detailed definition of each of them and providing an example to clarify their role inside the ICT for Energy Efficiency in Buildings field and taking into account the findings of the previous sections.

Each partner has contributed to a specific Priority Area, following its main expertise, by a deep review of the different research topics; in Table 2 it is shown the association between areas and partners. The only partner not involved in this activity has been VTT, this decision has been taken considering their deep involvement on the Classification preparation during the REEB project, that could have brought to a biased review of the different topics. However VTT provided a deep and detailed explanation and support about the REEB classification that facilitated the other partners work.

**Table 2: Association between REEB Priority Areas and Partner**

| REEB Area | Partner |
|---|---|
| Tools for EE design AND production management | DAPP |
| Intelligent control | SCHNEIDER |
| User awareness AND decision support | MOSTOSTAL |
| Energy management AND trading | SAP |
| Integration technologies | ATOS |

## 3.1 Tools for Energy Efficient Design and Production Management

The energy usage of a building is mainly determined in its design stage. Thus integration of model based tools and systems are probably the greatest potential of ICT for Energy Efficiency in Buildings. This category includes activities focused on the development of:

- Advanced Design Support Tools and Design Integration;
- Production Management;
- Advanced Simulation and Modelling Tools.

Starting from the taxonomy presented for each priority area in “D3.2 REEB map...”[3] of the REEB project, in Figure 3 is detailed the structure of this priority area. This graphical representation of the taxonomy allows to visually identifying the conceptual structure of the research topics related to “Tools for Energy Efficient Design and Production Management”. Each sub-category is distinguished by a different colour, and the rounded rectangles identify the different research topics.

[3] http://www.ict-reeb.eu/objects2/REEB_D3-2_ProjectMap_m19_released.pdf

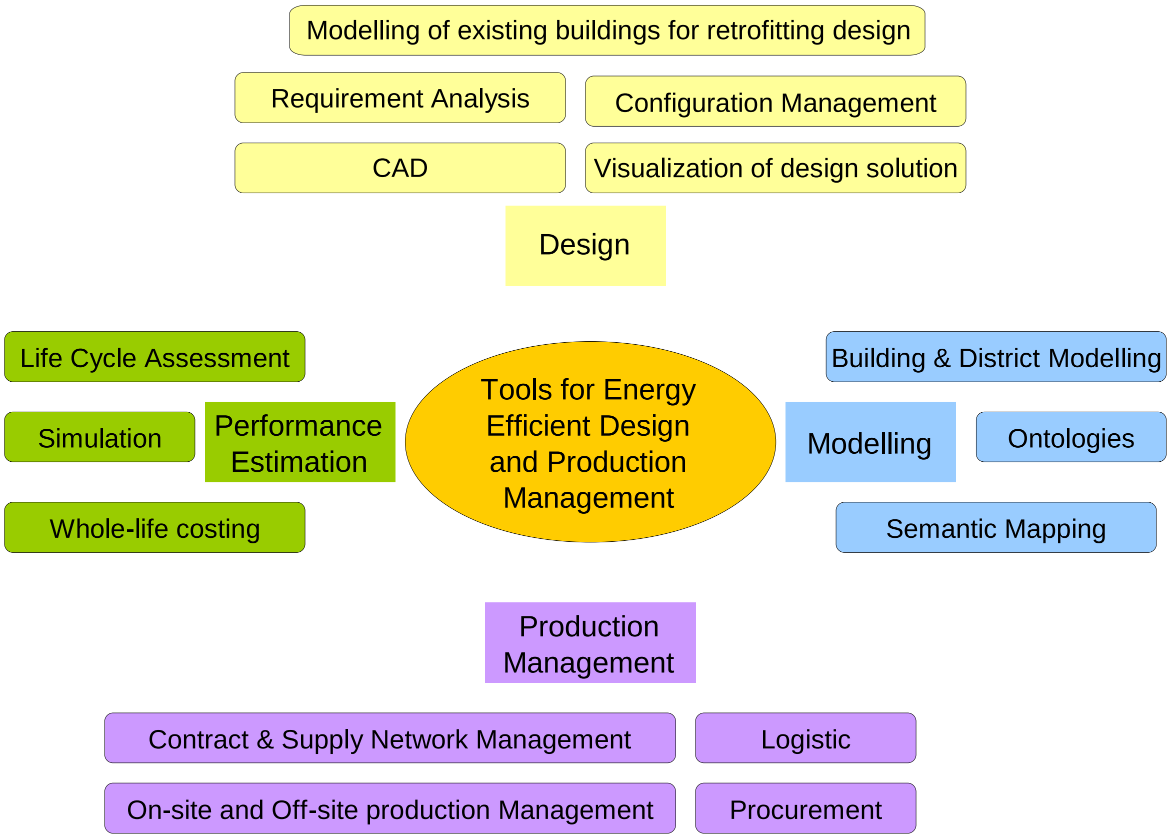


**Figure 3: Tools for Energy Efficient Design and Production Management**

It is important to notice that from the REEB classification two new research topics have been added (Requirement Analysis and Modelling of existing buildings for retrofitting design) considering that these topics are strictly linked to system design, really fundamental in design activities.

### 3.1.1 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 and configuration 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.

In Table 3 is provided the classification of the research topics related to the "Design" main topic.

**Table 3: Classification of the Research Topics Related to the "Design" Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **CAD** | Computer-aided design (CAD) is the use of computer technology for the process of design and design-documentation. The use of CAD tools is useful in order to enable engineers and customers to easily understand the impacts and complexity of design changes and to visualise the interaction of high-performance components for E2B. | Architecture, district, design/urban planning, civil engineering construction projects or plant of general wiring piping and air conditioning.<br><br>Nowadays a huge list of design tools commonly used in construction design is such as design tools (3D "dumb" solids and 3D parametric solid-modelling) and mid range software (integrating parametric solids):<br><br>Top end systems offer the capabilities to incorporate more organic, aesthetics and ergonomic features into designs. |
| **Configuration management** | It is a field of management that focuses on establishing and maintaining consistency of a system's or product's performance and its functional and physical attributes with its requirements, design, and operational information throughout its life.<br>CM provides an opportunity to thoroughly assess the impact of acquisitions, proposed changes in terms of ultimate cost, technical strength, and business need. CM also reduces overlap and redundancy in systems, assists budget and performance integration, and integrates administrative systems with respect to functions and data. In the scenario of E2B the use of CM is related to industrialisation of construction. The current design tools focus on "design from scratch" while the need is that design should be "industrialised" moving from "re-inventing the wheel" to re-using proven solutions & previous knowledge. | Detailed design becomes closely related to product and system development while "configuration design" is applied to assemble and customise pre-existing "template" solutions to project specific solutions: In particular configuration management would allow propagating specific design solution among different advanced CAD applications. |
| **Visualisation of design solutions** | It is necessary to support decision making (by many stakeholders) by visualising the impacts (e.g. on energy efficiency) of design alternatives. | Related to CAD, it can be possible to visualize the innovative components, devices or simply solution designed and related to energy efficiency such as smart lighting, HVAC piping system. Combined with simulation capabilities, all stakeholders can be provided with customised visual information about the energy performance (e.g. "early stage energy design" to demonstrate to clients the performance of their asset before they decide to construct i.e. 'try before you buy' or to test alternative courses of action i.e. 'what if' analysis). |
| **Requirement Analysis** | Requirements analysis (term coming from System Engineering) encompasses those tasks that go into determining the needs or conditions to meet for a new or altered product, taking account of the possibly conflicting requirements of the various stakeholders, such as beneficiaries or users. | Related to CAD application, requirements analysis it allows to start design from functional requirements, taking automatically into account the constraints coming from different stakeholders and avoiding accessibility issues from an early stage design. Again, as example new methods are |

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| | | needed for profiling (current and future) users. |
| **Modelling of existing buildings for retrofitting design** | The necessary information for retrofitting design of existing buildings is in most cases inadequate, not computer-readable, outdated or inaccurate.<br><br>Methods are needed for modelling of existing buildings using and integrating a variety of available information sources. The challenge is to create a baseline model of the existing building that allows the use of effective modern ICT tools in the design and subsequent retrofitting process.<br><br>Once this baseline model is created the subsequent steps can be carried out using similar ICT-based methods as for new buildings. The main difference is the need to manage (integrate / inter-link) information with multiple levels of semantics and more versatile meta-data. | Information sources that can be used for modelling of existing buildings include:<br>• Paper drawings can used as reference, or scanned and vectorized;<br>• CAD files may need to be transformed into currently supported formats;<br>• Photographs and videos can be used to identify details, material types and conditions;<br>• Laser scans can be used to provide reference geometry (point clouds) to be overlayed with the 3D model of the target building and for generation of surface models;<br>Thermal images can be used to identify poorly performing building parts. |

## 3.1.2 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.

In Table 4 is provided the classification of the research topics related to the “Production Management” main topic.

**Table 4: Classification of the Research Topics Related to the “Production Management” Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **Contract & supply network management** | Contract & supply network management: the first is the management of contracts made with customers, vendors, partners, or employees. Contract management includes negotiating the terms and conditions and incentives regarding energy in contracts and ensuring compliance with the terms and conditions, as well as documenting and agreeing on any changes that may arise during its implementation or execution. It can be summarized as the process of systematically and efficiently managing contract creation, execution, and analysis for the purpose of maximizing financial and operational performance and minimizing risk. The second one is the management of a network of interconnected businesses involved in the ultimate provision | Contract management software automates the contracting process from contract creation and negotiation through monitoring, compliance and renewal. The solutions typically maintain a warehouse of corporate contracts improving a company's access, visibility and control over contacts. Most solutions also offer the ability to warehouse standard contract and business terms and conditions and template contracts. E-catalogues of manufacturers and suppliers will contain information of their energy-related performance. Contracts are formulated in a way to provide incentives towards whole life |

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| | of product and service packages required by end customers. | performance of the building. |
| **Procurement** | Procurement is the acquisition of appropriate goods and/or services at the best possible total cost of ownership to meet the needs of the purchaser in terms of quality and quantity, time, and location. Corporations and public bodies often define processes intended to promote fair and open competition for their business while minimizing exposure to fraud and collusion. | Delegate third parties the production and development of any kind of stuff (structure, window, roof, water piping, heating) useful to reach the goal of energy efficiency in building. |
| **Logistics** | Logistics is the management of the flow of the goods, information and other resources in a repair cycle between the point of origin and the point of consumption in order to meet the requirements of customers. Logistics involves the integration of information, transportation, inventory, warehousing, material handling, and packaging, and occasionally security. Logistics is a channel of the supply chain which adds the value of time and place utility. Today the complexity of production logistics can be modelled, analyzed, visualized and optimized by plant simulation software. | Logistics management is that part of the supply chain which plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customer and legal requirements. Reducing the transportation distance via optimised logistics planning; integrated logistics from multiple suppliers and local procurement Can provide ICT enabled energy efficiency in the entire building life-cycle. |
| **On-site and off-site production management** | On-site and off-site production management is the approach used to produce a finished product. In first case all the necessary components are produced and then assembled by the same factory, while in the second case component are provided by different sources and then assembled. | Planning tools plus production management system to optimise on/off-site production considering EE impacts and to have a real time control on the production activities to manage the entire production chain done inside e outside the building site. |

## 3.1.3 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, not only for a single building but for whole districts.
Finally, it is essential to develop an approach that allows the integrated access of BIM-data and data to document the building performance history.

In Table 5 is provided the classification of the research topics related to the “Modelling” main topic.

**Table 5: Classification of the Research Topics Related to the “Modelling” Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **Building & district modelling** | Building & district modelling is the process of generating and managing building/district data during its life-cycle. Building information modelling covers geometry, spatial | Most information that is created and used in construction processes is still presented as documents e.g. drawings. This kind of information can only be |

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| | relationships, light analysis, geographic information, quantities and properties of building components (for example manufacturers' details). BIM can be used to demonstrate the entire building life cycle, including the processes of construction and facility operation. Quantities and shared properties of materials can be extracted easily. Scopes of work can be isolated and defined. Systems, assemblies and sequences can be shown in a relative scale with the entire facility or group of facilities. | interpreted by humans and needs to be manually entered into other ICT tools. The required human effort limits the exploitation of already generated information for new useful purposes. Building and District modelling allows to share information among the different actors and identify the different issues related to the building. |
| **Ontologies** | Ontology is a formal representation of knowledge as a set of concepts within a domain, and the relationships between those concepts. It is used to reason about the entities within that domain, and may be used to describe the domain. | Energy efficient smart buildings are characterized with complex interactions between people and devices, and at the higher hierarchical level, themselves are involved in interactions with other energy consumers and energy suppliers. All this information, interactions and measured data can formally described by ontologies. A shared and agreed ontology structure shared among different BIMs would allow an easier and more exploitable integration among the different components. |
| **Semantic mapping** | Semantic mapping is a process similar to data mapping or data integration, with the difference that here the semantic relationships are made explicit through the use of semantic nets or ontologies which play the role of data dictionaries in data mapping. Commonly refers to the process of data integration. | Semantic mappings would allow to maintain the conceptual constraints and inter-relations among the different components of a BIM and, at deeper level, of the design models. This would permit an easier sharing of information among products of different vendors and the re-use of components in different projects. |

### 3.1.4 Performance Estimation

Recent RTD activities focused on the development of Energy Simulation Packages to support the design phase in energy performance estimation. 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 supported by a few 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.
Furthermore this kind of simulation shall be developed in order assess the building through its whole life-cycle, both at cost and impact level.

In Table 6 is provided the classification of the research topics related to the “Performance Estimation” main topic.

**Table 6: Classification of the Research Topics Related to the "Performance Estimation" Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **Simulation** | Simulation is the imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviours of a selected physical or abstract system.<br>Simulation software tools are developed and used in many contexts, such as simulation of technology for performance optimization or safety engineering | In the contest of EE in Buildings simulation tools can be used to show the eventual real effects of alternative conditions and courses of action. Simulation is also used when the real system cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist. Fast indoor airflow simulations are necessary for building emergency management, preliminary design of sustainable buildings, and real-time indoor environment control. |
| **Whole-life costing** | Whole-life cost, or Life-cycle cost (LCC), refers to the total cost of ownership over the life of an asset . Also commonly referred to as "cradle to grave" or "womb to tomb" costs. Costs considered include the financial cost which is relatively simple to calculate and also the environmental and social costs which are more difficult to quantify and assign numerical values. Typical areas of expenditure which are included in calculating the whole-life cost include, planning, design, construction and acquisition, operations, maintenance, renewal and rehabilitation, depreciation and cost of finance and replacement or disposal. | Whole-life cost estimation, with the aid of simulation tools and BIM, can help and early design energy efficiency assessment of a building, making a clear estimate of the expected costs and therefore the ROI of any given energy efficiency measure considered at design, construction, maintenance, refurbishment and disposal level. |
| **Life cycle assessment** | A life cycle assessment (LCA, also known as life cycle analysis, eco-balance, and cradle-to-grave analysis) is a technique to assess each and every impact associated with all the stages of a process from cradle-to-grave (i.e., from raw materials through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). LCA's can help avoid a narrow outlook on environmental, social and economic concerns. The goal of LCA is to compare the full range of environmental and social damages assignable to products and services, to be able to choose the least burdensome one. | Insert a LCA tool in a Building Design Software or even a BIM Software would allow to know at early stage the whole impact of a building, in order to avoid design choices able to negatively impact the footprint of the building. |

## 3.2 Intelligent Control

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.

Starting from the taxonomy presented for each priority area in “D3.2 REEB map...”[4] of the REEB project, in Figure 4 is detailed the structure of this priority area. This graphical representation of the taxonomy allows to visually identify the conceptual structure of the research topics related to “Intelligent Control”. Each sub-category is distinguished by a different colour, and the rounded rectangles indentify the different research topics.

Intelligent control is an attractive option to improve energy performance in existing buildings. The cost of replacing or installing automation equipment with increased intelligence is typically low in comparison with e.g. improving the building shell.

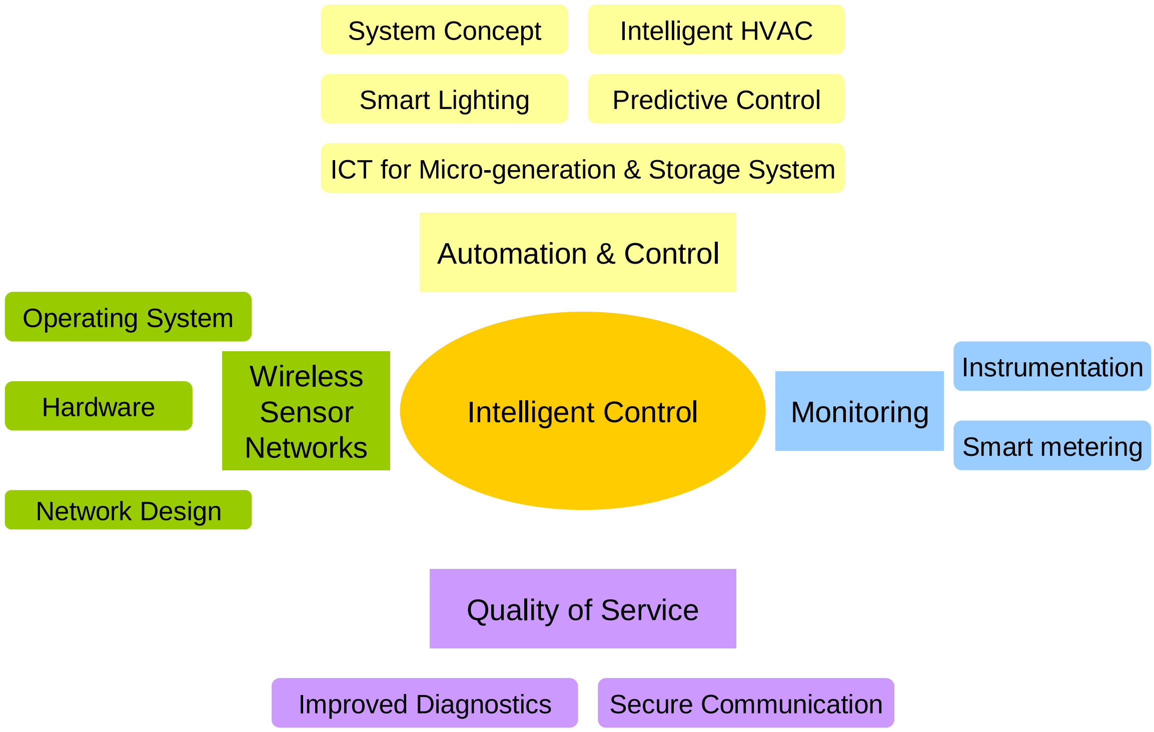


**Figure 4: Intelligent Control**

### 3.2.1 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 and intelligent lighting.

In Table 7 is provided the classification of the research topics related to the “Automation and Control” main topic.

**Table 7: Classification of the Research Topics Related to the “Automation and Control” Main Topic**

| Research Topic | Definition | Example |
|---|---|---|

[4] http://www.ict-reeb.eu/objects2/REEB_D3-2_ProjectMap_m19_released.pdf

| | | |
|---|---|---|
| **System concepts** | A system is a set of interacting or interdependent system components forming an integrated whole. In the framework of ICT for Energy Efficiency in Buildings, the system concept implies the use of new holistic approach to the control of all the different sub-systems deployed and active in the building. | Energy Management System able to make interactions among HVAC control and access control, allowing energy savings by modifying heating and ventilation under the person presence inside the building. |
| **Intelligent HVAC** | An Intelligent HVAC is an advanced HVAC controller able to go beyond the usual PID control, allowing the use of predictive, self-learning and supervised learning algorithms, taking into account also additional parameters coming from the sensors and meters deployed in the building. | The development of a Building Energy Management Systems (BEMS) with automation and self-adaptation to change of operational conditions of the HVAC, taking also into account building/grid energy balancing. |
| **Smart lighting** | Developing new light sources, managed by intelligent control system in order to minimize the consumption of energy into the indoor environment of the building. | Development of new light sources (e.g. LEDs + OLEDs), ICT-enhanced lighting control (through occupancy sensors, daylight and ambient light sensors, dimming systems). |
| **ICT for micro generation & storage systems** | 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.). This will be useful in order to balance the power load request by the building. | Optimized BEMS able to balance local energy production, storage and consumption, allowing reduction of energy bills and CO2 emissions. |
| **Predictive control** | Predictive Control actions are not only based on current and past information but also on forecasting of future building and external factors behaviours, allowing to improve maintenance, diagnose failures and optimize components performances. | Weather forecast or energy price affects control decisions, or a mathematical model can predict future behaviour of the building |

## 3.2.2 Monitoring

Recent RTD activities are allowing all stakeholders (users, energy providers, energy managers) through smart metering, visualisation of energy usage and performance data analysis, to visualise and analyse energy consumption in real-time, take appropriate measures and/or propose adapted services.

In Table 8 it is provided the classification of the research topics related to the “Monitoring” main topic.

**Table 8: Classification of the Research Topics Related to the “Monitoring” Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **Instrumentation** | Equipment of a building with sensors and data acquisition system useful to visualize and analyse energy consumption in real-time.. | Collecting and storing data from all parts of the building, allowing building management system to have a comprehensive information of the building actual status. |
| **Smart metering** | With the term “smart metering” are intended models for communicating meters, interoperation between (networks of) smart meter(s) and (energy providers) information systems. The smart meter’s essential functions are to measure, record, and communicate energy usage; communicate information for | 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. |

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| | outage management; and enable automated provisioning and maintenance functions, such as connection or disconnection of service. Smart meters also measure the flow of power into the grid from distributed generation or storage resources located at the customer's premises. Smart meters have historically been designed with a service life measured in decades, and the cost recovery period set by regulators is at least a decade. Thus, once a meter is installed, it remains there for a very long time as the interface to the electric utility. The smart meter is owned by the utility and is at the interface between the distribution and customer domains. | |

### 3.2.3 Quality of Service

Quality of Service (QoS) is the ability to provide different priority to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow. RTD activities are necessary to provide improved diagnostic tools and secure communication inside the built environment.

In Table 9 it is provided the classification of the research topics related to the "Quality of Service" main topic.

**Table 9: Classification of the Research Topics Related to the "QoS" Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **Improved diagnostics** | Improved diagnostic is the detection of malfunctioning devices and/or of sub-optimal building behaviours at physical and logical level. | 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.). |
| **Security and safety of information and communication** | Currently self-diagnosis systems exist and some sensors can also monitor their own functioning, and the communication protocols those used also include error detection in the data frame. In order to keep high the "quality of service" it is necessary to satisfy specific requirements in terms of availability, reliability, privacy, security and safety for communication protocol that it means that the meaning of shared information cannot know by third parties and the information delivered is the right one (authenticity and integrity). | 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. |

### 3.2.4 Wireless Sensor Networks

Research activities 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.

In Table 10 it is provided the classification of the research topics related to the "Wireless Sensor Network" main topic.

**Table 10: Classification of the Research Topics Related to the "Wireless Sensor Network" Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **Hardware** | Systems and equipment able to sense and meter data for energy use/production/storage in buildings. In the context of E2B it is important to dispose of advanced technology hardware in order to manage accurately the energy request and to reduce the energy consumption and the emission of CO2. | Wireless sensor able to harvest energy from the environment capturing e.g. temperature and gas concentrations using light energy. This is particularly interesting for retrofit due to the reduced installation cost. |
| **Operating system** | Algorithms and architectures for any configuration of the sensors hardware and the smart devices to be able to dynamically evolve according to the environment or change in a choice of a global strategy of energy efficiency in buildings. | 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** | The process of design the topology of a network of sensors, adapting it to the actual condition, it can be a manual process as well as an automatic process developed in real-time in order to achieve the best configuration possible to sense and meter data accurately in order to decrease the energy consumption. | 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. |

## 3.3 User Awareness and Decision Support

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.

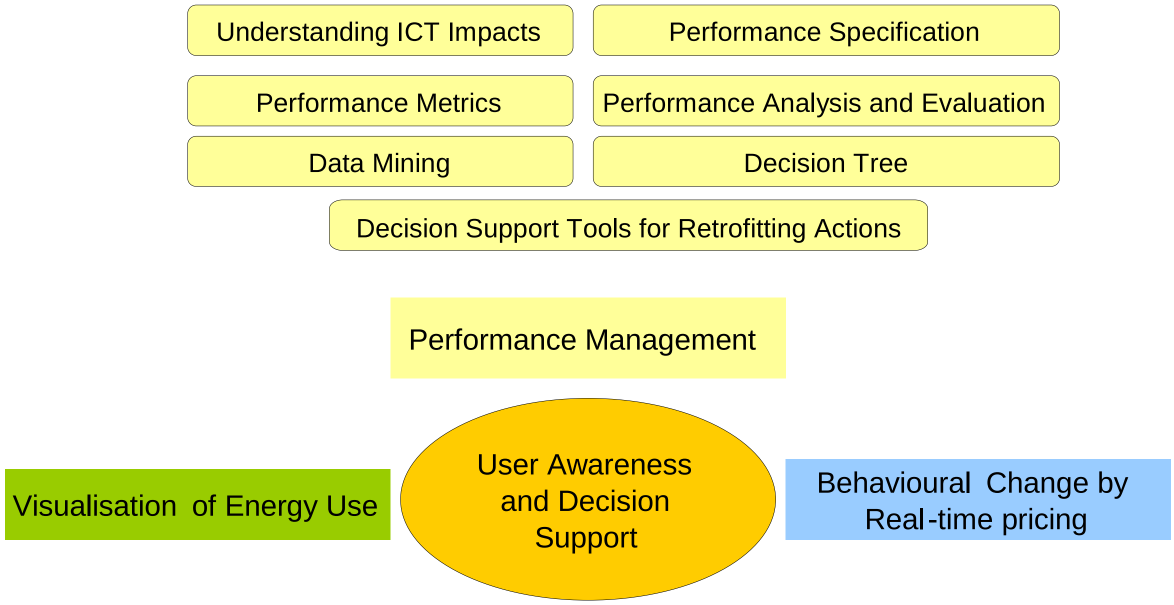


**Figure 5: User Awareness and Decision Support Tools**

Starting from the taxonomy presented for each priority area in “D3.2 REEB map...”[5] of the REEB project, in Figure 5 is detailed the structure of this priority area. This graphical representation of the taxonomy allows to visually identify the conceptual structure of the research topics related to “User Awareness and Decision Support”. Each sub-category is distinguished by a different colour, and the rounded rectangles indentify the different research topics.

It is important to notice that from the REEB classification three new topics has been added following section 2 analysis (Data Mining, Decision Tree and Decision Support Tools for Retrofitting Actions) and four term has been erased (Conformal Validation, Audit, Labelling and Commissioning) since they are already contained inside the topic Performance Analysis and Evaluation.

## 3.3.1 Performance Management

Recent research in Artificial Intelligent (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

[5] http://www.ict-reeb.eu/objects2/REEB_D3-2_ProjectMap_m19_released.pdf

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.

Decision support platform for building envelope retrofits, heating system and appliance replacement purchases, and on-site renewables integration. This will deliver a step-change in the provision and accuracy of retrofit advice to householders leading to a low-energy and low-carbon future housing stock. The outcomes will be of benefit to: energy, ICT, embedded systems and telecommunication companies developing technology and business models for Smart Home services; consumers to lower their energy bills and improve the safety, security and comfort of their homes; building component, boiler and appliance manufacturers developing the next generation of low-energy products; and policy makers for new insights into innovative approaches to meeting the security, affordability and carbon reduction aspirations of the energy system.

In Table 11 it is provided the classification of the research topics related to the "Performance Management" main topic.

**Table 11: Classification of the Research Topics Related to the "Performance Management" Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **Understanding ICT impacts** | Develop models and methods to assess and visualize the ICT impacts implies to clearly details and assess the impact of ICT solutions in the specific sector of energy efficiency in buildings. Understanding how ICT can help to realize European 3x20 strategy, decrease energy consumption and help to protect the environment, through a detailed analysis of each possible actions and its consequences. | Assess the energy saving provided by controlling heat energy use in the building basing on the meteorological data collected in the real time. |
| **Performance specification** | Methods and tools to describe the functional performance criteria required for a particular equipment as well as an entire control system deployed in a building to maximize the energy efficiency. | There exist several national regulations related to energy performance specifications in buildings, for examples BREEAM in UK, HQE in France and LEED in USA. The capability to customize design tools to answer to this performance specification already at design level would give a great added value, allowing to clearly address the energy efficiency level of a given design. |
| **Performance metrics** | Set of indicators to quantitatively and/or qualitatively assess performance requirements. There is a need to verify/assess the EPBD implementation. Energy labels/certification is performed in a "static way" and there are no methods, no data to establish a performance metric in dynamic/living building behaviour | A typical example of energy efficiency performance metric is the energy demand per unit of surface (W/m2). For example a BEMS should be able to calculate in real-time this metric for the controlled building in order to give a clear assessment of the energy saving performances. |
| **Performance analysis and evaluation** | Methodologies for analysing and assess specific performance specification through identified performance indicators. | A tool able to support the evaluation of performances, integrated in a Building Management System, allowing to know at any time the |

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| | | actual performance of the energy efficient operation through different perspectives.. |
| **Decision Tree** | Focusing on improvement of buildings' EE performance analysis, this available technology is a decision support tool that uses a tree-like graph or model of decisions and their possible consequences, including chance event outcomes, resource costs, and utility. It is one way to display an algorithm. Decision trees are commonly used in operations research, specifically in decision analysis, to help identify a strategy most likely to reach a goal. | Energy Efficiency decision trees, developed starting from well known operational standards as IPVMP, can be used to optimize components' performance specification by assessing different operational choices. |
| **Data mining** | Data mining is the process of extracting patterns from data. Data mining is seen as an increasingly important tool by modern business to transform data into business intelligence giving an informational advantage. | Data mining tools able to analysis Building Management System logging data and to extract performances and behavioural information from those data. |
| **Decision support tool for retrofitting actions** | A decision support system (DSS) is a computer-based information system that supports consumers in decision-making activities. In this case the decision support tool will be tailored on energy efficiency retrofitting actions of buildings. | Decision support platform integrated in a Building Management System to support future actions for retrofitting building envelope retrofits, heating system and appliance replacement purchases, and on-site renewables integration. This will deliver a step-change in the provision and accuracy of retrofit advice to householders leading to a low-energy and low-carbon future housing stock. |

## 3.3.2 Visualisation of Energy Use

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.

## 3.3.3 Behavioural Change

These RTD activities are focused on those solutions 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.

Moreover, there are a number of challenges in providing advice for retrofit solutions to consumers which will promote behaviour change and influence purchasing decisions. Currently consumer information is based on standardised methodologies for nominal house types and the resulting predictions of energy savings have minimal resemblance to reality where the thermal efficiency of the dwelling, efficiency of heating system and appliances, occupancy, user behaviour and preferences will have a significant impact on the effectiveness and uptake of retrofit measures. One solution is to provide consumers with personalised, accurate and trustworthy predictions of energy saving measures which are calibrated and tailored to their dwelling and living patterns, presented in a format to engage and promote action. Technologies like real-time measurements, advanced data analytics, digital signal processing and communications techniques, novel visualisation, semantic web and cloud computing technologies can be exploited to generate advice at different levels of abstraction for informed and justified decision making for retrofitting actions.

## 3.4 Energy Management and Trading

This category includes the RTD development of methodologies and tools for efficient energy management on all levels (e.g. urban, district, grid, building, room, area). Starting from the taxonomy presented for each priority area in “D3.2 REEB map”[6] of the REEB project, in Figure 6  is detailed the structure of this priority area. This graphical representation of the taxonomy allows to visually identify the conceptual structure of the research topics related to “Energy Management and Trading”. Each sub-category is distinguished by a different colour, and the rounded rectangles indentify the different research topics.
It is important to notice that from the REEB classification one new topic (Energy Service Interface - ESI) has been added following the relevance of this subject in the context of smart building connected to smart grid[7].

Getting ready for the smart grid era where energy management and trading are possible, makes a lot of assumptions for the underlying infrastructure and its services. While modern buildings can adhere to these new requirements, older buildings will need some retrofit. The latter implies introducing new cabling (or preferably wireless connectivity where applicable), upgrading light controls as well as replacement of pneumatic HVAC controls, and generally digitizing information that can be obtained to measure buildings behaviour as well as enabling management of the infrastructure). Nevertheless this still remains a costly activity,

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[6] http://www.ict-reeb.eu/objects2/REEB_D3-2_ProjectMap_m19_released.pdf
[7] NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0 - Office of the National Coordinator for Smart Grid Interoperability

especially for buildings over 15 years old. It should be kept in mind that retrofitting has multiple angles targeting sustainability and is not only relevant to energy but to other aspects as well e.g., water management, quality of materials, safety of operation for its occupants etc. Hence retrofitting impacts the whole building lifecycle, part of which is the envisioned smart grid as well as the here mentioned topics of energy management and trading.

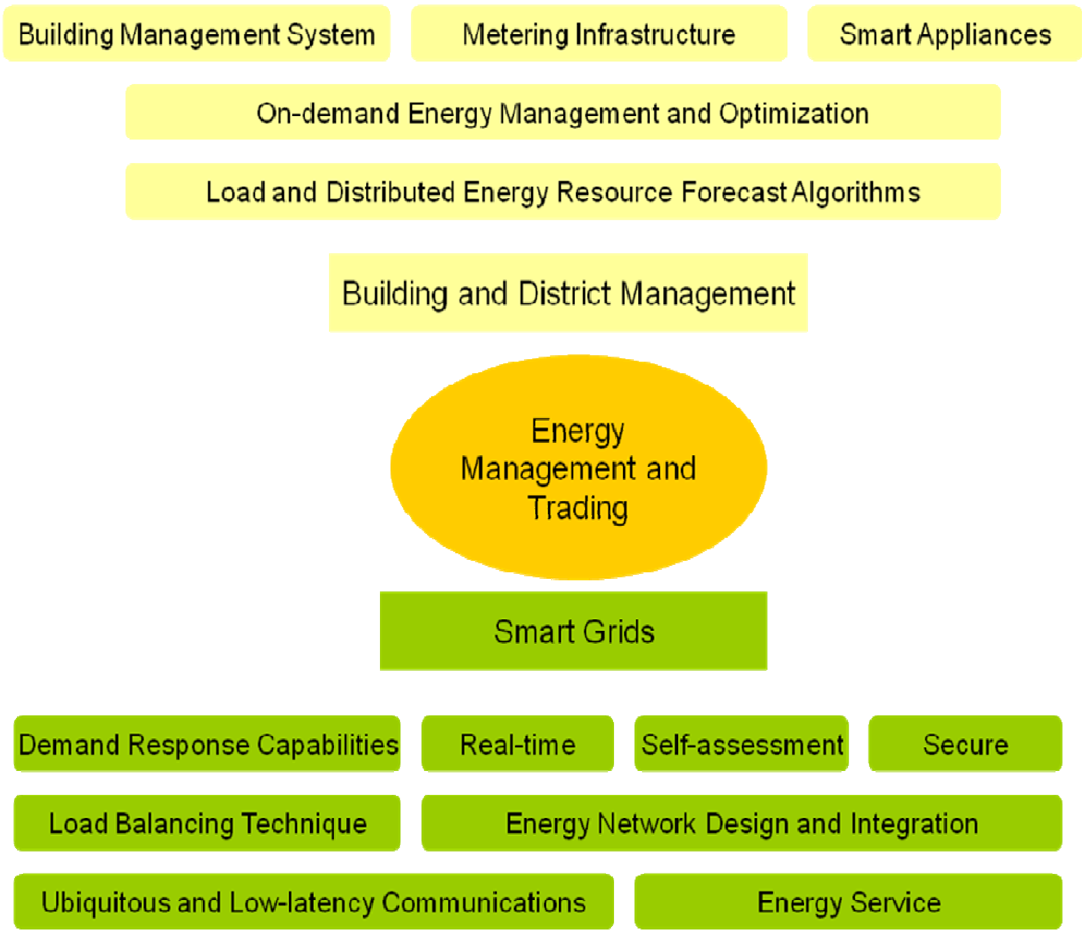


**Figure 6: Energy Management and Trading**

### 3.4.1 Building and District Energy Management

Research activities focused on the development of Energy Management systems able to cover energy issues at building and broader level.
Starting from the capabilities of a BMS to be fully integrated with the grid, exploiting peak supply as well as renewable energy, this research areas cover all the components and equipment able to support the building/facility manager to fully reach the goal of energy efficient management. In
Table 12 it is provided the classification of the research topics related to the “Building and District Energy Management” main topic.

**Table 12: Classification of the Research Topics Related to the “Building and District Energy Management” Main Topic**

| Research Topic | Definition | Example |
| --- | --- | --- |

| | | |
|---|---|---|
| **Building management systems** | The use of IP protocol to communicate with and control small devices and systems opens the way for the convergence of large, IT-oriented networks with real-time and specialized networked applications. The synergy of the access and potential data exchange opens huge new possibilities. The next generation building management systems will monitor probably over Internet technologies thousands of metering devices providing fine-grained information about the energy consumption and/or production. Retrofitting of older buildings with wireless and economically sound add-ons is of key interest. | Building Management System (BMS) and Specialty Systems have the potential to integrate over IP services with business systems leading to a vision of the "converged" network[8].<br><br>Future BMS are expected to not only monitor at large scale energy related information, but also do actuation and be self-configuring by adjusting to external conditions or strategies. Today we only have standalone BMS but the trend is towards collaborative ones that do real-time monitoring and decision support. |
| **Advanced Metering Infrastructure** | Energy management heavily resides on monitoring i.e. metering as a first step. An advanced metering infrastructure (AMI) that would provide high resolution metering data is needed. AMI would operate in a timely manner (tending towards real time), implying rapid collection of metering info and transmission to the metering system. Additionally the AMI may provide also fine grained information on the breakdown of the measurements e.g. per prosumption device. Generally AMI accommodates business scenarios such as real-time usage information, individual usage prediction to better manage supply, fault detection, accommodation of new tariff models such as time of use (TOU), block of use (BOU), etc. . As meters are replaced with new ones, there is no differential treatment of older (retrofit) and new buildings. | In the longer term, any kind of device within a building infrastructure e.g. HVAC, IT system, sensor, lamp etc. can be considered as a meter which may be connected to the AMI. Commercial systems implementing AMI exist today by major metering companies / utilities. However these need to be further pushed towards real-time, high-resolution metering and accommodate thousands of devices. Products include hardware/software AMI, meter data management, metering/analysis software. |
| **On-demand energy management and optimisation** | Energy management and optimisation will be moving towards production-driven consumption. Optimisations will be done by considering complex information such as weather prediction, energy price, schedules of the appliances, business processes etc. and will lead to energy consumption optimisation to decrease bills cost. For older buildings, (wireless) actuators will need to be installed (retrofit). | Building energy related processes are adjusted depending on the available energy and costs. |
| **Load and distributed energy resources forecast algorithms** | By integrating real-time information coming from the appliances and energy monitoring systems, with context information e.g. business process, situation, scheduling etc. one may achieve much better forecasting of the production or consumption of the energy. This high precision info can then be fed to simulators that can evaluate changes in the infrastructure they monitor and suggest adjustments which the management systems (e.g. BMS) can immediately follow to save the maximum quantity of energy. As such better forecast models and algorithms that integrate actuation capabilities must be developed. | Enhancement of existing algorithms to include real-time data analytics (big data) including behavioural models and impacts based on fine-grained information coming from buildings, people, devices, systems etc. |
| **Smart appliances** | Information and Communication Technologies (ICT) is increasingly embedded in appliances and | Typical smart appliances will be household ones e.g. washing |

[8] Stamatis Karnouskos, JP Vasseur, Patrick Wetterwald, Jerald P. Martocci, Ted Humpal, Ming Zhu, "The Internet of Things and the Convergence of Networks", IPSO Alliance, RTC Magazine (http://rtcmagazine.com/articles/view/101879)

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| | devices in general, realising the vision of the Internet of Things where billions of devices will have communication and computation capabilities participating in Internet scale collaborations. The appliances of the future are expected to be able to not only report their energy consumption (monitoring) but also allow external management (control) or internal self-management towards goals such as energy efficiency, decrease of $CO_2$ emission and decrease of overall energy related bills. | machines, fridges etc., but also HVAC systems, security systems, routers, IT systems etc. The smartness will emerge from context sensing and adaptation of their functionality in a standalone or in collaboration with other devices [9]. Older buildings as part of their retrofit process,will become more intelligent by integrating such smart appliances. |

## 3.4.2 Smart Grid and the Built Environment

The Smart Grid is a complex system of systems. RTD activities aimed at extending the smart grid within the home consumer appliances and devices can be controlled remotely, allowing for sophisticated demand response (DR).. Advanced decision support algorithms would enable the individual devices in cooperation with higher level systems to co-decide if energy consumption could be adjusted for specific timeslots in order to lead to energy usage optimisations.

In Table 13 is provided the classification of the research topics related to the Smart Grids main topic.

**Table 13: Classification of the Research Topics Related to the "Smart Grids" Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **Demand response capabilities** | Demand Response capabilities enable short-term changes by customers in their accustomed electric consumption patterns to reduce or shift electric load over time. These changes are usually made in response to incentives e.g. payments with the aim to reduce electricity use for a specific timeframe. This short-term behaviour can improve electric grid reliability and inhibit rise in electricity prices. Empowered with new ICT, appliances and systems can now automatically and in real-time adjust to external signals e.g. price signals and therefore demand-side management can be done at a large scale and in a targeted optimised way. As such we can realize energy conservation, optimizing allocation of resources and ensure reliability of electric grid by reducing or shifting the electric demand. Retrofitting in older buildings will enable them to include monitoring and control capabilities via the introduction of intelligent devices. | Distribution monitoring, control software, and demand/cost response software. |
| **Real-time self-assessment** | The buildings are a key part of the smart grid. They are expected to collaborate and depict self-X features i.e. self-configuration (automatic configuration of components), self-healing (automatic discovery and correction of faults), self- | The building monitors its behaviour and identifies faults and in cooperation with the enterprise system a workflow is started for its maintenance, ordering of parts to be |

[9] ◦Pedro José Marrón, Stamatis Karnouskos, Daniel Minder, and Aníbal Ollero, editors. The emerging domain of Cooperating Objects. Springer, 2011.

| | | |
|---|---|---|
| | optimization (automatic monitoring and control of resources to ensure the optimal functioning) and even self-protection (proactive identification and protection from arbitrary attacks). In order to guarantee integrity, uptime and security of supply, appliances and systems must do self-monitoring and assessment of several internal and external conditions in real-time. Although there are systems that depict partially such functionality, we have hardly scratched the surface of what such real-world systems should really support. Self-assessment assumes fine-grained monitoring capabilities and this implies high retrofit investments for older buildings. | used during the repair, cost estimation of the process etc. |
| **Load balancing techniques** | Grid optimization incorporates a wide array of potential enhancements that need to be done at service providers, grid operators, end-users etc. Being able to accommodate distributed generation and storage, as well as bidirectional communication among all entities enables us to do better energy management, track the balance of supply and optimise its usage. | Typical examples are storage heaters running demand-response tariffs, or a vehicle-to-grid system to use storage from electric vehicles during peak times and then replenish it during off peak times. |
| **Energy network design and integration** | Energy networks can no longer be planned in a standalone fashion as their communication infrastructure will be shared with various other networks public or private communication network, both wired and wireless. As such network design and integration tools will be needed, especially when it comes down to resources that are shared or have an effect on other infrastructures. Typical asset data information, analytics, visualisation tools, operational data etc. are needed in conjunction with enterprise services in order to optimally plan and integrate energy related devices and processes. In the same way<br>Given this variety of networking environments, the identification of performance metrics and core operational requirements of different applications, actors, and domains - in addition to the development, implementation, and maintenance of appropriate security and access controls - is critical to the Smart Grid. | IP-based network by design is easily scalable; any new Smart Grid devices, such as smart meters, smart home appliances, and data concentrators in neighborhoods, could be added to the network.<br>As the scale of IP-based network for Smart Grid expands, the numbers of devices connected to the network will increase substantially. The widespread use of IPv6 (which many companies already demonstrate today for embedded devices) for new systems to be developed and deployed. |
| **Secure Ubiquitous and low-latency communications** | Smart Grid information and controls flow through many networks with various owners, hence it is critical to properly tackle security, trust and privacy issues. This encompasses measures to ensure the confidentiality, integrity and availability of the electronic information communication systems and the control systems necessary for the management, operation, and protection of the Smart Grid's stakeholder interactions among multiple fixed and mobile channels as well as various other applications. Since the energy related information will be used not only for billing but also for other value-added services, it has to be guaranteed that this is done with security and privacy in mind at all layers and in a timely (near real time) manner. For older buildings where retrofit is needed, wireless technologies are expected to play a key role in order also to minimize costs and deployment effort. | With smart meters measuring and communicating electricity flows often e.g. every 15 minutes, connected parties could potentially derive information about consumer's profile e.g. sleeping, eating and vacationing habits. Ensuring the highest standards of data privacy cannot be overlooked, and the requirements include security policies, procedures, and protocols to protect Smart Grid information and commands in transit or residing in devices and systems.. |
| **Energy Services** | The interaction between the Smart Grid and the customer domain is of special importance. It will be | New and innovative energy-related services, which we may not even |

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| | the most visible part of the Smart Grid to the consumer. The customer as well as other stakeholders such as energy systems, are expected to interact over open interoperable services and mash them up in order to provide more sophisticated functionalities. Hence it is important to have standardized base energy services that are common for all, and upon which extensions and more complex approaches can be built. | imagine today, will be developed. These will depend on new insights gained to the collected data. It is therefore imperative to consider data openness and easy integration into basic energy services. Extensibility and flexibility are important considerations. As heterogeneous entities may consume these services, e.g.. devices and controllers, such as thermostats, water heaters, appliances, consumer electronics, and energy management systems, we must ensure that simple yet effective approaches can be realized. |

## 3.5 Integration Technologies

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.

Starting from the taxonomy presented for each priority area in “D3.2 REEB map...”[10] of the REEB project, in Figure 7 is detailed the structure of this priority area. This graphical representation of the taxonomy allows to visually identify the conceptual structure of the research topics related to “Integration Technologies”.

[10] http://www.ict-reeb.eu/objects2/REEB_D3-2_ProjectMap_m19_released.pdf

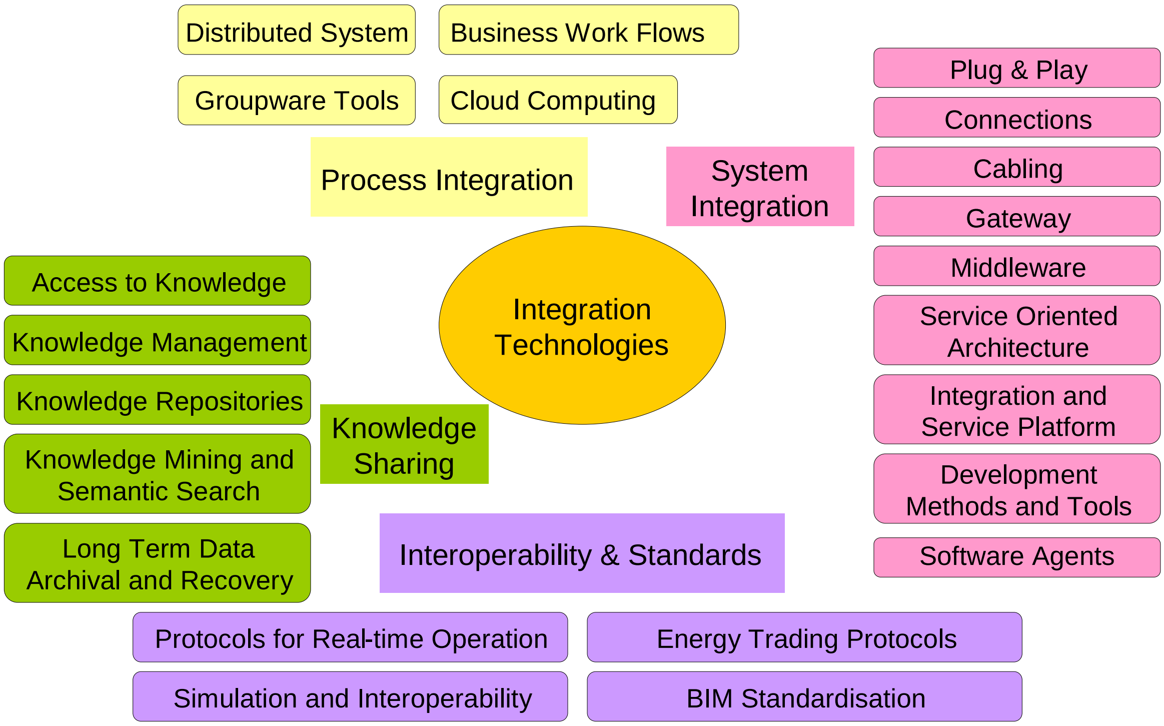


**Figure 7: Integration Technologies**

It is important to notice that two new topics has been added with respect to REEB classification, Clouds computing and Software Agents. Electronic Conferencing and Collaboration Support have been removed since it is already integrated inside Collaboration Support and Groupware tools. Finally the macro-area “Virtualization of the Built Environment” has been removed.

### 3.5.1 Process Integration

Current processes integration in building is mainly based on digital files that are shared by several stakeholders. In many cases, these files are “flat files”, without semantic value, as “doc” or “gif” files, without semantic value, that require their understanding and handling by human experts. At the same time, workflows are manually managed, been the email the main tool to support the interaction among the stakeholders during the design process, and paper documents the mechanism to certify contractual agreements and responsibilities in the building process. RTD activities to overcame this limitations by exploiting ICT solutions capabilities are actually on-going and shall be further enhanced.

In Table 14 is provided the classification of the research topics related to the “Process Integration” main topic.

**Table 14: Classification of the Research Topics Related to the “Process Integration” Main Topic**

| Research Topic | Definition | Example |
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| **Groupware tools** | An application software that integrates work on a single project by several concurrent users at separated workstations. The design intent of collaborative software (groupware) is to transform the way documents and rich media are shared in order to enable more effective team collaboration among the stakeholders during the design process of new energy efficient buildings. | - Collaborative working environments (CWE) will blur the border between work, leisure and social activities and relations.<br>- Self-configurable systems: Future collaborative working environments will be able to learn and adapt to various working and collaboration styles and to different legal and regulatory conditions (semi-) automatically.<br>- Dynamic virtual teams: Collaboration support services are commercially available to temporary, distributed, cross-organisational project teams.<br>- Inter-enterprise interoperability: Future CWEs will allow the employees of each organisation to use their familiar in-house systems that are synchronised with the collaboration environments of project partners in a transparent and secure way.<br>- E-Legal: Web based contract negotiation, enactment and conflict resolution will be legally valid without replication with traditional document/paper based procedures. At the same time, digital signature and digital certificates will guarantee the authoring and authenticity of any digital document.<br>- Monitoring and control via Internet: Data that are managed by the control system has to be opened through Internet to other applications, even externals to the building, in such a way that these applications can work with better information. |
| **Distributed systems** | A distributed system consists of a collection of autonomous computers, connected through a network and distribution middleware, which enables computers to coordinate their activities and to share the resources of the system, so that users perceive the system as a single, integrated computing facility. The vision is that ICT tools for EEB will be developed as a dynamic integration platform that is able of discovering in the web the most accurate modules to perform the functionality that is requested by the user, taking into account also the specificities on every building project (local regulations, local building practices…). | - Service Oriented Applications (SOA). A service-oriented architecture is essentially a collection of services which communicate with each other. The communication can involve either simple data passing or it could involve two or more services coordinating some activity.<br>- Distributed Data Base applications. A distributed database is a set of databases stored on multiple computers that typically appears to applications as a |

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| | | single database.<br>Consequently, an application can simultaneously access and modify the data in several databases in a network.<br>- Lightweight Directory Access Protocol (LDAP). LDAP lets you "locate organizations, individuals, and other resources such as files and devices in a network, whether on the Internet or on a corporate intranet," and whether or not you know the domain name, IP address, or geographic whereabouts. |
| **Business work flows** | It used to describe the tasks, procedural steps, organizations or people involved, required input and output information, and tools needed for each step in a business process. The vision is seamless integration and automation of the building life cycle business workflows, including management and technical processes. | Current market tools available are, e.g. Microsoft BizTalk, Windows Workflow Foundation and SAP Business Workflow. A step beyond would be the capability of integrate such tools together with BIMs allowing to manage business flows at the information management level. |
| **Cloud computing** | Is Internet-based computing, whereby shared servers provide resources, software, and data to computers and other devices on demand, as with the electricity grid. Cloud computing is a natural evolution of the widespread adoption of virtualization, service-oriented architecture and utility computing.<br>In the scenario of process integration this technology, related to the internet of things and the rapidly growing of IPv6, is involved to ensure a high level on Quality of Service. | The major cloud service providers include Rackspace, Amazon, Salesforce, Microsoft and Google. |

### 3.5.2 System Integration

Regarding Intelligent control within a building or a buildings neighbourhood, a wide variety of different technologies, from different vendors and companies, are coexisting.
Consequently, information exchanged through these technologies is heterogeneous. It doesn't have the same meaning from one system to the other and data are defined regarding each particular technology. Another problem is the lack of a common standardized infrastructure and middleware in order to facilitate System integration.
An envisaged way of progress on the topic of System integration is the definition of a Service Oriented Architecture platform able to communicate with the devices installed in a building (or neighbourhood of buildings). This platform requires the definition of some middleware components behaving like gateways or bridges between it and the multiple installed devices.
Finally, and after the global infrastructure has been initialized, the most difficult effort is to define a common vocabulary amongst all the system(s) components, in order to be able to reuse the solution as a generic pattern, in many buildings, ideally working with many kinds of pluggable devices.

In Table 15 is provided the classification of the research topics related to the "System Integration" main topic.

**Table 15: Classification of the Research Topics Related to the "System Integration" Main Topic**

| Research Topic | Definition | Example |
| --- | --- | --- |
| **Plug & play** | Each new component in a building is automatically discovered as well as its primitive functions for information access. And by analogy, the principle would be the same at the neighbourhood level, where each new building or each new energy generation unit would be detected and seamlessly integrated in the district energy network. It will lead to highly flexible and scalable networks, where new components can be easily included, existing ones removed, or defective ones detected and isolated from the network (that will possibly show reduced functionalities, but will still work). In addition, this will go with a self - (re)configuration of the system without need of manually reconfiguring the network. | |
| **Connections** | Many different communication systems and protocols will continue to exist in the future (dedicated bus cables, radio communication, power line communication/PLC…). The challenge is to make them coexist and interoperate in a seamless way by developing open and technology-agnostic integration platforms. Interoperable connections and protocols will allow holistic provision, operation, monitoring and maintenance of systems. 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 to have the total control of energy consumption in buildings. | Currently available communication protocols are ZigBee and Wi-Fi. The adaptation of such protocol to the need of the built environment would allow to easily introduce wireledd sensor networks. |
| **Service oriented architecture** | Integration of BIM, real time information and support services: Service oriented architectures (SOA) integrate BIM-based applications, real time systems and external services (e.g. security, remote operation, maintenance, energy saving etc.). Buildings become integral parts of enterprise information systems. | |
| **Integration and service platform** | An Integration Platform tries to create an environment in which engineers can integrate all kind of applications (independent from platform, programming language or resource) so they can bound together in workflows and processes to work in conjunction in order to achieve the goal of energy saving. | Common platform rather than separate hardware, hosts systems and programming languages that can be used to program and manage components that are developed by any manufacturer. |
| **Software agents** | In computer science, a software agent is a piece of software that acts for a user or other program in a relationship of agency, which derives from the Latin agere (to do): an agreement to act on one's behalf. Such "action on behalf of" implies the authority to decide which (and if) action is appropriate. The idea is that agents are not strictly invoked for a task, but activate themselves. In the scenario of system integration in building field the use of software agent is useful to manage and monitor the state, the availability of the devices. | Monitoring and Surveillance Agents are used to observe and report on equipment, usually computer systems. The agents may keep track of company inventory levels, observe competitors' prices and relay them back to the company, watch stock manipulation by insider trading and rumors, etc. |
| **Cabling** | The vision is the convergence of the telecommunications and building automation systems networks and that massive high speed | |

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| | data communications are supported by lighter and smaller diameter cables that enable efficient use of pathway spaces for improved airflow through racks and cabinets to maximize pathways and cooling efficiencies. | |
| **Gateways** | Gateways are H&S systems that allow communication and integration of several building sub-systems (with their associated services) in order to share the resources and functionalities of their different devices. A primary functionality of those gateways is to connect the building (smart building) to external life cycle support services (e.g. remote control, configuration, facility management applications of multiple buildings, security & comfort, etc) provided via the Internet or other WAN by smart grids and to share this connection between the different devices and sub-systems. A core part of a home gateway is its middleware.<br>Apart from providing a single usage node, future gateways will fully realize the convergence of several technologies (standard or proprietary ones) through a single device enabling a large range of services that will take advantage of the sharing of common resources to implement holistic strategies (including energy-focused strategies) in smart buildings. | Common examples of gateways are home boxes, and in general all the situation where it is necessary to integrated different devices exploiting different communication protocols and/or data models. |
| **Middleware** | To support new context-aware applications that will implement innovative building energy saving management scenarios, new middleware will be required. Those middleware will facilitate the dynamic integration of heterogeneous networked devices and related application services within the system, and exchange of context data among them, by providing appropriate high level features for all building system users, including service providers. Such middleware infrastructures will allow powerful services to be easily deployed and permit users to interact with them in a personalized but easy manner. Examples of key services provided by such middleware will include service discovery and service interoperability. Those middleware will incorporate requirements coming from the involved three worlds They will be preferably built on Open. | A current Middleware under constant development that could be adapted to the Smart Building environment is OSGI (Open Service Gateway Initiative). |
| **Development method and tools** | New applications and services for energy efficiency will require new hardware and software with higher computational power to run not only measurement/control tasks with huge and increasing volume of data & information, but more complex routines such as predictive algorithms, hot reconfiguration, and handling of large history databases.<br>To enable a wide and open growth of these solutions, a set of development methods and tools will be needed by the developers' community: this includes simulation and test environments, Integrated Development Environments (IDE), but also data models and schemas for unified development processes, such as XML schemas or UML based representations. | |

### 3.5.3 Interoperability and Standards

Currently, a lot of ICT tools are used along the building life cycle (design and simulation tools, management tools, control and monitoring systems, energy trading systems,…).
However, there is a lack of interoperability among them. Although standards exists, there are too much and fully independent standards. In some cases, several standards are competitors among them, as KNX and Lonworks in relation with building automation. In other cases, the lack coordination among complementary standards makes very complex the interoperability of the building sector ICT tools. Consequently, it is necessary to increase the interoperability among the current ICT tools, and also the future ones, that are applied along building life cycle.

In Table 16 is provided the classification of the research topics related to the "Interoperability and Standards" main topic.

**Table 16: Classification of the Research Topics Related to the "Interoperability and Standards" Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **BIM standardisation** | Within specific ICT tools, BIM is usually implemented in a proprietary way. Various application tools of different stakeholders are compliant with commonly agreed information definitions. For interoperability between different systems, both the meaning (semantics) and the format (syntax) need to be "understood" by the involved systems. The potential of standard-based BIM is to share the information and to manage buildings in a standard way by using consolidated models. | - Open standards will support interoperability of common software tools without re-entry and loss of meaning (semantics). In parallel, there is also room for non-standard and de-facto industry standard conversion methods for the same aims.<br>- Ambiguities are avoided by compliance certification and validation of software tools and interfaces.<br>- File managers: Data exchange between applications, e.g. via file transfer, supports sharing of versioned information (long transactions). This technology is already sufficiently mature to be applied between different legal entities under prevailing contract conditions.<br>- Model servers: A higher level of interoperability, and deeper collaboration between participants, is achieved by model servers enabling near real time information sharing. This technology is still in an early stage of development and is associated with challenges regarding model evolution management, business models, collaborative working procedures, contract conditions, liabilities, IPR etc.<br>- Digital catalogues: Manufacturers publish value adding product information |

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| | | including e.g. design rules, constraints and dynamic product. |
| **Simulation and interoperability** | The vision is that the data required for simulations will be available and interoperable from other tools e.g. design, modelling and automation & control. In such a way that building energy efficiency simulation is a seamless process from the definition stage to the usage stage. | Uncertainty management. The adoption of estimation/simulation tools during the building design process (and not only at the end of the process) implies that these tools need to manage the uncertainty that it is inherent to the design process. For example, it is need to simulate energy performance of the building before the detailed definition of the envelope. Consequently, the information that is provided by the BIM has to be complemented with other knowledge sources, as typical building solutions in this area, main preferences of the contractor, etc. |
| **Protocols for real time operation** | The vision is a BEM (Building Energy Management System) with seamless “in-door” and “out-door” integration, in such a way that full interoperability from the level of different manufacturer’s devices to the holistic automation and control of various subsystems and utilities (gas, electricity) SCADAs (Supervisory Control And Data Acquisition) to maximize energy saving. | - Open protocol makes real time data and information from buildings available to various operation & control applications, both for internal management of the building and its integration in smart grids. These open protocols should extend from low level protocols to standardized data models, in such a way that not only syntactic (formats) compatibility is achieved, but also semantic interoperability.<br>- Low energy consumption protocols minimize data interchange in order to extend the batteries life. |
| **Energy trading protocols** | Protocols that have been designed to make possible the interaction between buildings and ESCO/utilities and between smart buildings and smart grids. | IEC 61850 and DLMS-COSEM protocols have been already developed. The adaptation of this protocols with the available BEMS data models would allow an easier spread-out of this technology. |

## 3.5.4 Knowledge Sharing

There are limited if at all any mechanisms for the capture, structuring, and propagation of knowledge not only across organisations, but within organisations themselves. At best, some basic file/document management systems exist. Where forerunners are embracing web-based collaboration environments and even using syndication tools the knowledge stored in such solutions is limited and efficient means for its capture, structuring, and most importantly sharing are missing. There is limited support for interactive training, simulation, etc.

Efficient knowledge sharing practices are essential to overcome technological and economic barriers related to energy efficient  retrofitting of buildings; in this process knowledge across various organisations ( for example the original constructor of the building and the company that is performing the retrofitting) is essential.

In Table 17 is provided the classification of the research topics related to the “Knowledge Sharing” main topic.

**Table 17: Classification of the Research Topics Related to the “Knowledge Sharing” Main Topic**

| Research Topic | Definition | Example |
|---|---|---|
| **Access to knowledge** | The way to access to the knowledge related to efficient buildings using tools like e-learning, community forums and user awareness tools. | |
| **Knowledge management** | Organisations (regulatory bodies, designers, contractors, facilities management, owners, etc.) and increasingly buildings (including communities) through efficient semantic based knowledge management platforms identify, collect, organise, share, adapt, use, and create energy efficient solutions and practices. New good energy efficiency practices are where possible, translated to tangible programmable processes to be automated through ICTs with the goal to decrease energy use. | - Model-based knowledge management<br>- Ambient access technologies<br>- Knowledge platforms<br>- Standards |
| **Knowledge repository** | Consist in computerized system that systematically captures, organizes and categorizes an organization's knowledge. In the context on E2Bs it is necessary to store intelligent digital catalogues of building products/services, models of automated control system, the indicators and the methods to meter performance, to structure, to propagate and to share knowledge across national organization, construction organization and stakeholders in order to achieve the common goal of energy saving both in new energy efficient building and in old and renewable buildings | In this case can be useful catalogues:<br>- Intelligent digital catalogues of building products/services. They should contain substantial product/service information (much more than simple geometry) in parametric form. As an example, they could contain guidelines for the construction (how to build or how to use or how to make more energy efficient) of the product. Domain knowledge is available in reusable form from catalogues including e.g. energy efficiency related attributes.<br>- Template solutions: Reusable knowledge templates i.e. object with built-in configuration rules and constraints. These enable customisation of proven solutions without re-invention.<br>- Configuration rules allow simulation of different design combinations and provide means to optimised energy efficient solutions. Template solutions can be used to where possible translate identified good energy efficiency practices to tangible programmable processes to be automated through ICTs.<br>- Personalisation by means of user profiling the catalogues are able to provide customised information regarding both contents and |

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| | | presentation (format). Efficient knowledge sharing solutions are essential also in retrofitting of existing buildings. For example in this process it is necessary to share the knowledge between the original building constructor and the company that is performing the retrofitting |
| **Knowledge mining and semantic search** | Meta repositories, that will provide definitions of relationships, and mappings between different energy efficiency related information repositories, knowledge sources, ontologies and semantic knowledge services to retrieve the required information from the relevant and reliable sources. | The use of semantic search in a BIM environment would allow to easily retrieve all the relevant information related to a given part of the model. |
| **Long-term data archival and recovery** | Building life time is in the order of 100 years. Archived data may become non-accessible in a period like ~10 years due to: lack of devices that can read old storage media, new versions of the software that was used to create it, or evolution of the format standard. The vision is that archived data will be accessible after very long periods of time in order to improve the process of energy saving in buildings and districts taking care the progress of the literature, the studies, the models of automated control, the critical aspects of the intelligent control adopted so far achieved. This will be enabled by the definition and the diffusion of BIM standards, general archiving standards and services standards. | |

## 3.6 Summary of the Changes of ICT4E2B Taxonomy with respect to REEB Taxonomy

The following diagrams summarizes the changes and updates that have been made in ICT4E2B taxonomy with respect to REEB taxonomy already described in the previous sections for each technology area. Only for the technology area “Intelligent Control” no changes have been made.

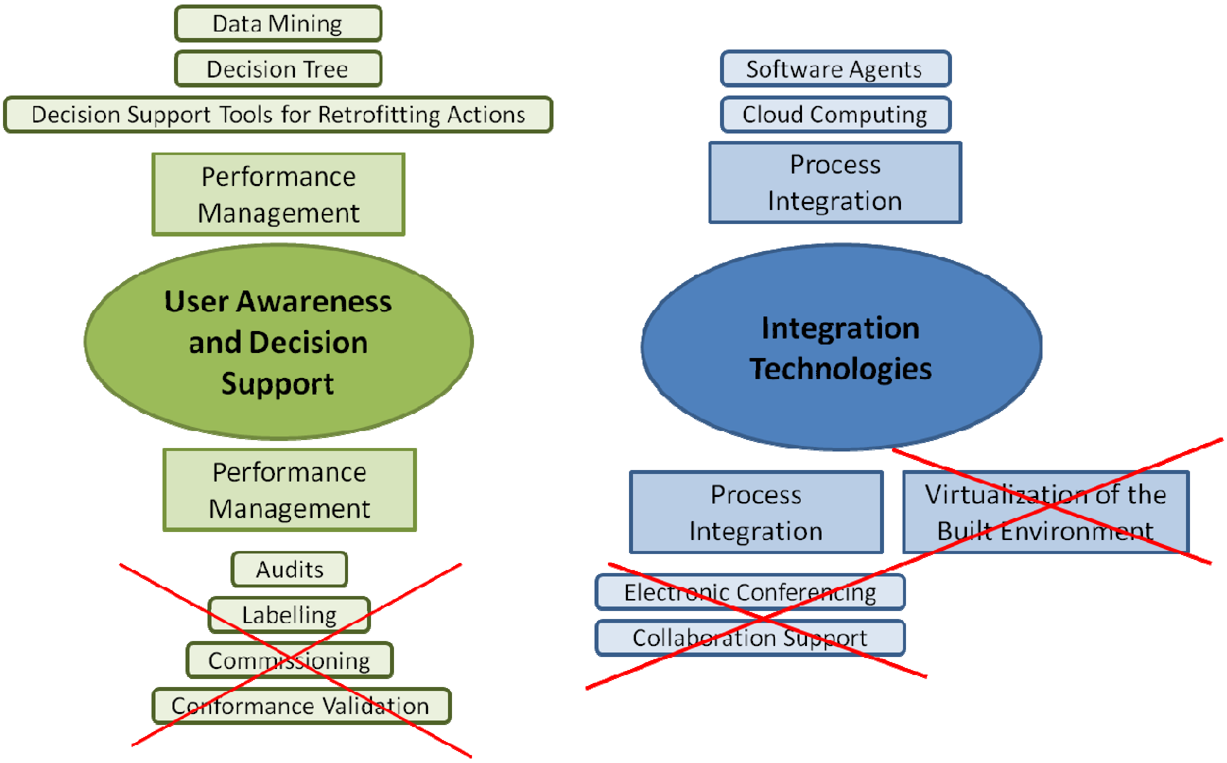


**Figure 8: Changes in ICT4E2B Forum taxonomy with respect to REEB taxonomy for the two technology areas "User awareness and decision support" (three topics added and four topics deleted) and "Integration technologies" (two topics added and two topics deleted, and the macro area "Virtualization of the Built Environment" deleted).**

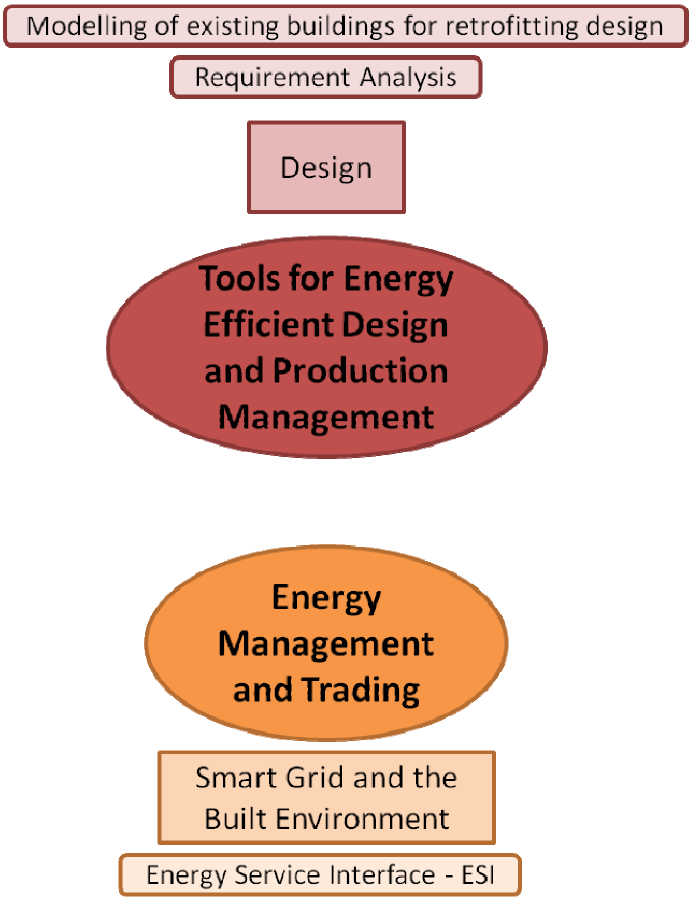


**Figure 9: Changes in ICT4E2B Forum taxonomy with respect to REEB taxonomy for the two technology areas “Tools for Energy Efficient Design and Production Management” (two topics added) and “Energy Management and Trading” (one topic added).**

# 4 Extension of the Scope towards Smart City Systems

This section envisions the extension of ICT4E2B scope to Smart City systems by re-elaborating the Smart City Model towards an extended scope that can embrace the complexity of energy efficient districts and cities.

## 4.1 The Smart City Model

A Smart City is a city well performing in 6 characteristics, built on the "smart" combination of endowments and activities of self-decisive, independent and aware citizen.
The reference system, i.e. the "starting point" used as basis of the analysis of how ICT support Energy Efficiency in Smart Cities, is represented by the model developed by the European Smart Cities project[11].

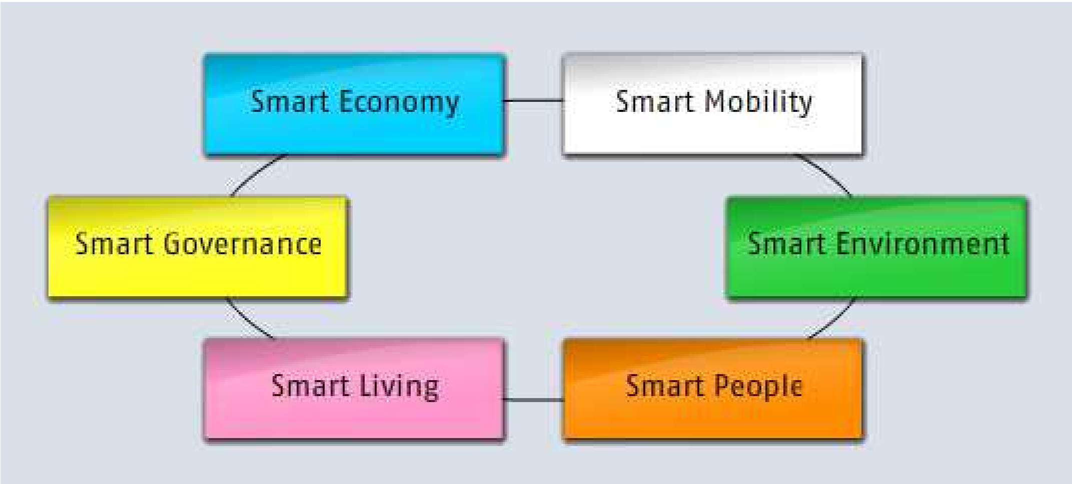


**Figure 10: Smart City Model**

With reference to the 6 characteristics in Figure 10 a specific list of key factors is provided by the model, each of them should be able to capture the different themes related to the different characteristics.

### 4.1.1 Smart Economy

The key factors and indicators for Smart Economy are:

- **Innovative spirit**: Indicators for this are considered e.g. R&D expenditure in % of GDP, Employment rate in knowledge-intensive sectors, Innovative spirit, Patent applications per inhabitant etc.

  *ICT4E2B assessment: Energy Efficient and Smart Building concepts and technologies may significantly boost these indicators. Especially when it comes down*

[11] "Smart cities - Ranking of European medium-sized cities", Smart Cities project (www.smart-cities.eu), October 2007. URL: http://www.smart-cities.eu/download/smart_cities_final_report.pdf

*to innovative R&D and patents. In the longer term, a leadership in the area may lead to higher employment rate.*

- **Entrepreneurship**: Indicators for this are considered among other the self-employment rate and new businesses registered, etc.

  *ICT4E2B assessment: Energy Efficient and Smart Building area may enable innovators to pursue their ideas either by creating their own companies or acting as knowledge consultants in the area, hence boosting this indicator*

- **Economic image & trademarks**: Indicators for this are considered e.g. importance as decision-making centre (HQ etc.)

  *ICT4E2B assessment: If a leadership is established in a smart city, then it is expected that decision making centres will be also moved to the point of action and demonstration i.e. the city as such.*

- **Productivity**: Indicators for this are considered e.g. GDP per employed person, etc.

  *ICT4E2B assessment: The creation of new jobs as well as knowledge driven economy may have a positive impact in GDP per employed person especially due to competitive start-ups.*

- **Flexibility of labour market**: Indicators for this are considered e.g. Unemployment rate, Proportion in part-time employment, etc.

  *ICT4E2B assessment: The establishment of innovation centers and a playground for new ideas may lead to less unemployment in the long term.*

- **International embeddedness**: Indicators for this are considered e.g. Companies with HQ in the city quoted on national stock market, etc.

  *ICT4E2B assessment: The Smart Cities that may offer a place for smart-city wide demonstrators of concepts and technologies may attract international publicity and also the creation of businesses (or transfer of them).*

- **Ability to transform**: Indicators for this are considered e.g. Air transport of passengers, Air transport of freight, etc.

  *ICT4E2B assessment: Increase in innovation in cities, will lead to increased visits for experiencing the newly established companies and events.*

### 4.1.2 Smart Mobility

One of the characteristics of a Smart City is Smart Mobility. Here the impact of Smart Mobility factors on information and communication technology for energy efficient buildings is addressed.

- **Local accessibility:** Local accessibility facilitates the mobility of people within cities and for it to be efficient a suitable ICT infrastructure is needed to manage and monitor the public transport system.

*ICT4E2B assessment: One possible overlap with ICT systems for buildings could be that the technology for payment interaction with passengers can also be used in a building to register presence of people or as a mean for tenant interaction in general, while preserving the privacy of individuals.*

*Another potential link is that the flow of people through the public transport system can indicate future building occupation, in particular for large facilities. Forecasted occupation is useful for predictive building control and Smart Grid strategies.*

- **Availability of ICT-infrastructure:** A building's access to a broadband internet connection is essential for many ICT applications targeting energy efficiency. Such applications include:

  *ICT4E2B assessment: Cloud based technologies such as remote energy monitoring would be inaccessible without it. Forecasted weather information for predictive building control can easily be shared. The Smart Grid is dependent on an ICT infrastructure.*

- **Sustainable, innovative and safe transport systems:** Electric cars are emerging as an alternative sustainable mean of transportation. There are benefits of interaction between the electrical charging of the cars and building ICT systems.

  *ICT4E2B assessment: A car park within an office building could act as energy storage for the building needs, facilitating Smart Grid interactivity.*

### 4.1.3 Smart Environment

A smart city promotes sustainable development aiming at reducing the amount of waste increasing recycling, and at reducting of greenhouse gas emissions by limiting traffic and optimization of industrial emissions. From EEB perspective, these objectives can be enlarged by the rationalization of building reducing the impact of heating and air conditioning system, the rationalization of public lighting, and at least the promotion, protection and management of urban green and remediation of brown field sites.
The terms of the retrieved taxonomy for this Specific Characteristic are detailed below:

- **Design innovation:** Municipalities need to keep high the attractive level of natural conditions protecting and managing urban green areas and reclaiming the brown field sites of the cities.
  *ICT4E2B assessment: In order to reach these objectives preliminary space plans and environmental analysis must be faced before designing new energy efficient buildings. The architects and engineers use interoperable BIM tools to design buildings and to estimate and evaluate the EE performance of a building from the very early design phase throughout the design process. During conceptual design, they obtain producer-independent information about different materials and system solutions. Since the conceptual design, quantifying tools for measuring EE and production management are used with product database, specifying the energy value of new innovative and EE materials and for better managing logistics issues (reduction of trucks and lorries traffic through the city implies air pollution and CO2 reduction).*

- **Environmental protection**: About 16% of global final energy consumption comes from renewables, with 10% coming from traditional biomass, which is mainly used for heating, and 3.4% from hydroelectricity. New renewables (small hydro, modern biomass, wind, solar, geothermal, and bio-fuels) accounted for another 3% and are growing very rapidly. Smart cities located near sea, harbour or river can increase the use of renewable energy exploiting a natural environmental element: the water. This element contributes to the building's reduction in energy usage halving the energy consumption.

  *ICT4E2B assessment: Rather than install an air-conditioning system, the architects and engineers use chilled-beam technology, in which a closed system of water cooled by the harbour circulates throughout the building, lowering the temperature and creating a natural convection current that circulates the air. During the design phases of the buildings designers must take into account the impacts related to the installation of this kind of application satisfying public finances, reducing energy consumption and maintaining an high level of comport for the citizen.*

- **Carbon footprint reduction for energy sustainability city**: Local communities have the goal to convince citizens to reduce their energy consumption enough to mitigate the effects of global warming. City's carbon footprint comes from the residential use of cars and homes. Buildings account for 40 percent of worldwide energy consumption and about 21 percent of all greenhouse gas emissions. At the same time, they represent enormous potential for improvement – with intelligent building technology and comprehensive energy solutions, up to 60 percent of their consumed energy can be saved. Because of this sustainable cities are looking at ways to improve their infrastructures to become more environmentally friendly, increase the quality of life for their residents, and cut costs at the same time.

  *ICT4E2B assessment: Reduction of carbon emissions is achieved by introducing fundamental improvements in the efficiency of urban infrastructure through ICT as follows:*
  - *ICT directly contributes both to energy usage and CO2 reduction. Industry efforts aimed at developing energy-efficient technology solutions can contribute to a sensible reduction of the environmental footprint in cities. But collaboration between government and industry, along with development of effective policy, are essential to a successful greening of ICT.*
  - *Deploying broadband-based applications and services improves energy efficiencies.*
  - *Urban pervasive broadband infrastructure and continuous development of application and services clusters can enable radically innovative practices in the areas of urban form and planning, energy policy, new working practices, and new lifestyles. ICT pervasiveness and the emergence of Web 2.0 are having dramatic implications on the socioeconomic tissue of a city, as well as on its energy-efficiency policy.*
  - *ICT and broadband connectivity have become enablers of combined, citywide urban policy, and of previously disconnected operational programs. Integration of data and processes across isolated government initiatives is becoming a reality.*

- **Rationalisation of public lighting:** The lighting of public space accounts for 60% of public energy use in an average city. It is clear that any reduction that can be achieved will have a significant impact on total energy use and, therefore, on CO2 emissions, without forgetting the positive effects on public finances.

*ICT4E2B assessment: Using lighting network as the backbone of a network of sensors it is possible transfer acquired data toward smart lighting controller and then, exploiting the city/district local network, send this information to computing cloud. The city's computing cloud analyzes the information stored in city's database. This kind of advanced metering infrastructure integrated to a load balancing system allows reduction of energy consumption changing the city in response to the input it has received.*
*In addition, smart lighting module (LED street lamp) can be used as informative display, fault detection and security system for street control in order to provide comfortable services to the citizen.*

- **Waste reduction:** Zero Waste is a goal which requires the designing and managing of products and processes to reduce the volume and toxicity of waste and materials and to conserve and recover all resources. Avoiding the production of a product or package or reusing it in its original form and thereby preventing waste altogether, offers the most significant greenhouse gas reductions of any solid waste management strategy. Preventing waste eliminates the need to extract resources, manufacture products and materials, transport them to market, and dispose of them as waste, avoiding the greenhouse gas emissions at each step of that process.

  *ICT4E2B assessment: With reference to the above* context prediction algorithm, *machine learning techniques and inter-building interactions system can be integrated together to acquire and apply knowledge about solid waste that comes from residential, commercial and construction/demolition (C&D) in order to define strategic waste management plan avoiding to reduce greenhouse gas emissions.*

### 4.1.4 Smart People

Without the people, a Smart City becomes little more than an interesting commodity — and that alone is not very smart.
In relation with buildings in a smart city, the behaviour of a building's users may be at least as important as its design when it comes to energy use.
The terms of the retrieved taxonomy for this Specific Characteristic are detailed below:

- **User awareness in energy consumption:** Energy is an increasingly valuable resource. In the design of everyday domestic environments, buildings and products, electricity and energy use is seldom made explicit. Therefore on the other hand, wiring, electrical meters, outlets and batteries are hidden away as much as possible inside walls, in elegant casings and in distant basements.

  *ICT4E2B assessment: The trend is to fill the home with smart technology and appliances for communication and entertainment with no concerns in relation to energy. It is important to engage user to the analysis of the consumption in their households in order to encourage them to find out how they can save energy using new ICT systems that are available in the their houses. It is a key factor to achieve the engagement of the user to new ICT technologies at homes to make them aware* *of the energy current necessities and the importance of not waste energy when it is possible.*

- **People's behaviour key factor for success:** Energy has important symbolic and behavioural aspects that can have as much impact on consumption as energy efficient equipment does. In many people's minds, energy "rationing" is a negative symbol of hard times, whereas energy consumption is a sign of prosperity. Saving energy therefore carries ambiguous connotations. In developing countries, using energy can be a symbol of progress and affluence; social recognition can come from consumption, which clashes with saving energy. In the developed world, it is a commodity that is taken for granted and its insignificance can lead to thoughtless waste.
  Lifestyle or habit may increase energy consumption. For example, people tend to prefer individual houses rather than apartments. Houses are also getting larger, with fewer people per household. In the EU, the number of households increased twice.
  There are two separate aspects of energy behaviour: buying efficient equipment and using energy efficiently.
  In Europe the market for appliances has changed over the last decade. Despite the price premium for energy efficient equipment, there was a switch to buying more energy efficient appliances. The flip-side of this is the trend to buying more equipment as people become wealthier: dishwashers, garden equipment, extra TVs and other consumer electronics. Barriers to energy efficient buying and use.
  The transition to using energy efficiently is difficult because it requires widespread changes in habits, ranging from turning off appliances when not in use to buying more energy efficient appliances. The balance between technical solutions for energy efficiency and human actions for energy efficiency needs to be weighed system by system.
  Consumers tend to want more user-friendly technologies and economic incentives such as bonuses for reducing energy use. But energy efficient behaviour can become almost automatic when trends in lifestyle, energy efficient technology and behaviours coincide. This emphasizes the importance of lifestyles and behaviour in energy consumption.

  *ICT4E2B assessment: Technical devices to measure energy consumption and provide immediate feedback help households to cut energy consumption by as much as 20%. Direct and immediate feedback reveals the link between actions and their impacts. Well informed consumers choose actions to save energy with minimal impact on their comfort. Perceptions of comfort are important; there must be a balance between energy-saving value and any perceived loss of comfort.*

- **Smart Society:** Smart Society is an essential evolution of the concept of Smart City, which allows us to include people who will make possible the transformation engines as well as beneficiaries and emphasizing the need for work in essential processes for technology to provide results with a greater impact on society in the medium and long term. If only circumscribe the concept of Smart technology we are doomed to failure, because on one hand will not get to optimize the services to which it is intended, and, secondly, we will not have the feedback from the rest of our ecosystem: the citizens, and extension, the inhabitants of our planet.

  *ICT4E2B assessment: Smart Society should go further and embrace innovation, collaboration, participation and transparency. For sure all related with engineering*

*and innovation, but from a philosophy of work to detect what exactly are the demands and expectations of society and decide how best to address them.*
*Any Smart initiative, apart from an economic or environmental return, you must have a social return, and it must necessarily pass through a new way to interact with the environment.*

### 4.1.5 Smart Living

Living life to the fullest is all about Smart Living. It is about making the wisest choices possible to constantly move forward and not backwards in life with the aim of energy saving and protect the environment. This concept can be considered valid for an apartment, as well as a building, perspective or even a District or City.

Below are short explanations how each item is related to the ICT4E2B technologies.

- **Cultural and education facilities**

  *ICT4E2B assessment: In addition, ICTs can be applied to optimise the use of facilities by offering them to various user groups in idle times. This can reduce the overall investments of the city. Secondary impacts include e.g. reduced traffic.*

- **Health conditions:** Indoor conditions in the built environment can be improved by means of monitoring sensors, automation and control.

  *ICT4E2B assessment: The necessary ICT infrastructure is already in place for energy management; only minor enhancements may be needed for achieving health-related impacts e.g. new sensors and control algorithms.*

- **Housing quality and Individual safety:** The successful design of a good quality sustainable housing project depends on the balance struck between a range of factors. Issues such as accessibility, security, safety, privacy, community interaction, availability of appropriate services and the provision of adequate space, should be given due weight. The needs and reasonable expectations of residents are of fundamental importance. The typical family dwelling will be required to meet the needs of infants, young children, adults and older people, either separately or in combination, at various stages of its lifecycle. The design should be sufficiently flexible and adaptable to meet such demands over the foreseeable life of the building.

  *ICT4E2B assessment: Housing quality can be improved by ICT-supported user centric provision, design/configuration and financing of homes. In addition, ICT systems for security (e.g. access control) are increasingly integrated with building energy management systems whereby both safety and energy efficiency impacts can be achieved with the same investments*

- **Touristic attractivity**

  *ICT4E2B assessment: Energy dashboards in public buildings and/or spaces can have high visibility to citizens and become attractions to visitors.*

- **Social cohesion:** People can use ICTs to benchmark their energy consumption patterns. This will encourage people to participate also in other community activities.

"Social cohesion is the capacity of a society to ensure the well-being of all its members, minimising disparities and avoiding marginalisation."
[Council of Europe, http://www.coe.int/t/dg3/]

*ICT4E2B assessment: Home automation systems, smart metering, energy dashboards and social media provide means for engaging citizens and communities in energy efficiency activities.*

### 4.1.6 Smart Governance

Smart Governance generally refers to overall management system that allows owners to coordinate across many different smart systems. “Smart” has many meanings, however main stress is put on use of ICT technologies in mechanisms of decision-making, public and social services, political strategies and perspectives.
“Governance” is a continuous process; it does not have an end unless there are parties involved. There can be specified and detailed key factors for Smart Governance:

- **Participation in decision-making:** Public consultations are becoming widely used good practice. Good policies and decisions do not change anything if the communication is poor, therefore decisions need to be communicated in the best way to have an impact.
  In some cases, consultations are required by Environmental Impact Assessment mechanism, which can be powerful system for the interested parties. In this case, lack of agreement or even a protest made by the stakeholders can suspend investment process or strategic national or international documents (in case of Strategic Environmental Assessment).

  *ICT4E2B assessment: An access to the network is the same important as proper services. Therefore integration and development of the public wireless network must be foreseen in the smart cities. Public network has to be secured in order to assure privacy data.*

- **Public and social services:** Improving government services, transactions and interactions with citizens and businesses is one of the main issue in the public service. Possibility of setting formalities without “leaving home” is the very tangible result of smart governance. This include issues like:

  - Taxes accounts
  - Social insurances
  - ID documents
  - Vehicle registration
  - Building permits
  - Library access
  - Legal acts
  - Statistical data
  - Customs declarations
  - Others

  Solutions allowing for this kind of on-line formalities have certain advantages:

  - Proximity to citizens

- Accessibility
- Usability
- Sustainability
- Interoperability

*ICT4E2B assessment: In order to achieve full result it is necessary to guarantee:*

- *Secure connection and validation of users*
- *Data security*
- *Trust in the technology*

*With all the technologies and advantages of the system it is possible to implement successful e-government system and increase convenience of inhabitants and stakeholders.*

*There are technologies that can bring directly energy efficient applications to the end users. One of the technology is a data base with energy performance of buildings. People who would like to buy o rent a flat/house could first take a look on the database (stored on the local government servers) and check what energy performance has the building. Because of EPBD act implementation more and more private buildings and almost all of public buildings will have the energy performance certificate. Database will allow users to search buildings with low energy consumption and cause impact among the owners to improve energy performance of their buildings as they will become less competitive to others.*
*Local communities, having an access to the data of the building, can propose a government supported solutions leading to decrease of energy consumption. Any incentives, loans and other information can be provided to those with very high energy consumption. Other technologies leading to energy efficiency on a broader level are based on GIS (Geographic Information System) solutions. All kinds of interactive maps can provide useful information to the end users regarding energy. Map with transportation, traffic jams zones, easy connections can persuade inhabitants to use public transportation or alternative means of transportation. Map of solar insulation together with meteorological data can give knowledge about possible solar gains and renewable energy potential. All this information presented by authorities in a interactive way can be a good basis for more energy efficient society.*

- **Political strategies and perspectives:** Similar to decision making process, some of the political strategies should be consulted with the society. It has a greater meaning in local communities, where most of the decisions have direct influence on the community. A great role in this case performs Non-Governmental Organisations (NGOs), formed by all the interested people. NGOs can have greater impact in the process of political governance as mostly they have rights to undermine decisions in the front of court.

  *ICT4E2B assessment: Information Technology and Information Highways are able to stay and impact our life in the year to come.*

- **Transparent governance:** Transparency is one of the most important component of the process of governance. Every change needs to be transparent to assure people that all the privacy and security issues were fulfilled.

*ICT4E2B assessment: Information technology should be integrated into the process of government functioning with an aim to bring about simple, moral, accountable, responsive and transparent (SMART) governance to its people. Smart governance has to be also auditable to prove that quality and transparency had been kept on the high level.*
*Governance that is not auditable, open and transparent might become corrupt.*

## 4.2 Relation of Smart City Model to Smart City Systems Application Areas

The 6 Smart City model areas constitute the reference point to define the concept of energy efficient neighbourhood and city that can be further elaborated in 5 application areas to envision the extension of ICT4E2B Forum scope towards Smart City systems. This elaboration has been done in parallel with IREEN project where it was also necessary and useful to start from the Smart City model to elaborate the application areas of the energy efficient urban and rural neighbourhood. Clearly the resulting extension for ICT4E2B Forum towards the Smart City system maintains its main focus on buildings, while in IREEN the focus is much broader by including all aspects of an energy efficient neighbourhood, considering also transport related aspects.
The defined application areas for the Smart City System are reported in the following paragraphs.

### 4.2.1 Built Environment

This area considers all kinds of energy consumers in the city/neighbourhood from the point of view of their interconnections including the following subareas:

- Buildings: considers all kinds of buildings in the area; small buildings, apartment buildings, offices, services buildings etc., chiefly from the point of view of their interconnections at the neighbourhood level.
- Public Spaces and Lightning: all aspects related to public spaces including the lightning system
- Waste management: all aspects related to a correct and efficient management of waste.

The following diagram shows the relation between the Smart City model categories and the Built Environment application area and sub-areas of the Smart City systems.

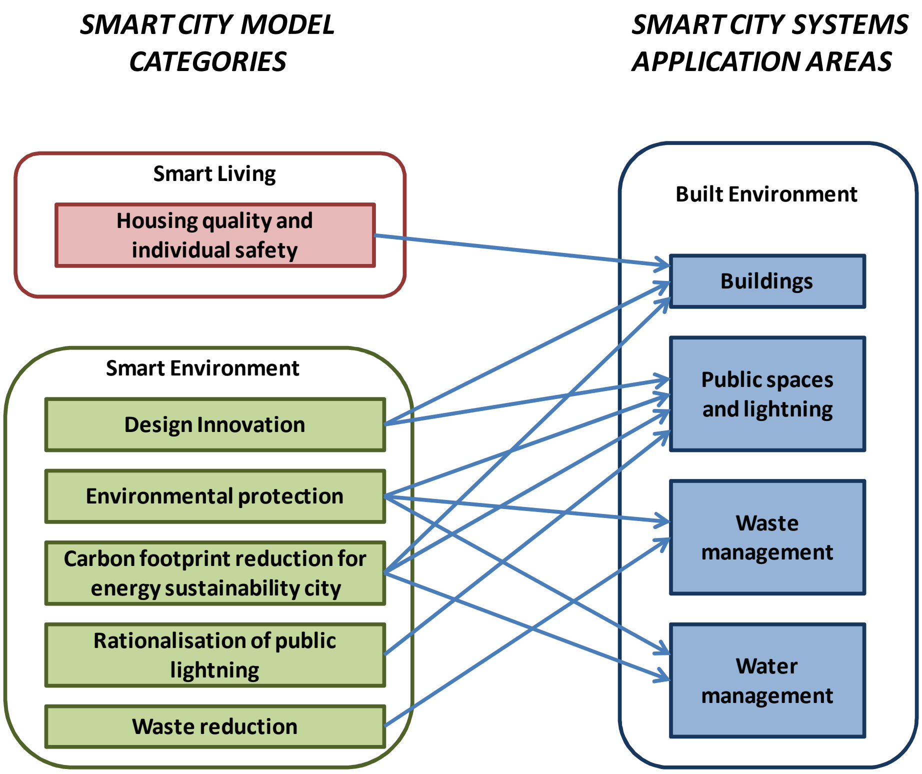


**Figure 11: Relation between categories of the Smart City model and the Built Environment application area of the Smart City system**

## 4.2.2 Energy Systems

This area considers all systems for the productions and distribution of energy in the city/neighbourhood. Energy production systems can be both centralised and distributed. This includes all forms of energy: electricity, heating, cooling, gas, and fuels. By considering the energy efficient terminology to taking the primary energy into account, also the energy source can be considered.

- Electricity systems: all systems aimed at producing and distributing electricity within the city
- Heating and cooling production and storage: all systems related to the production and distribution of heat and cooling
- Gas network: all systems related to production/distribution of gas.

The following diagram shows the relation between the Smart City model categories and the Built Environment application area and sub-areas of the Smart City systems.

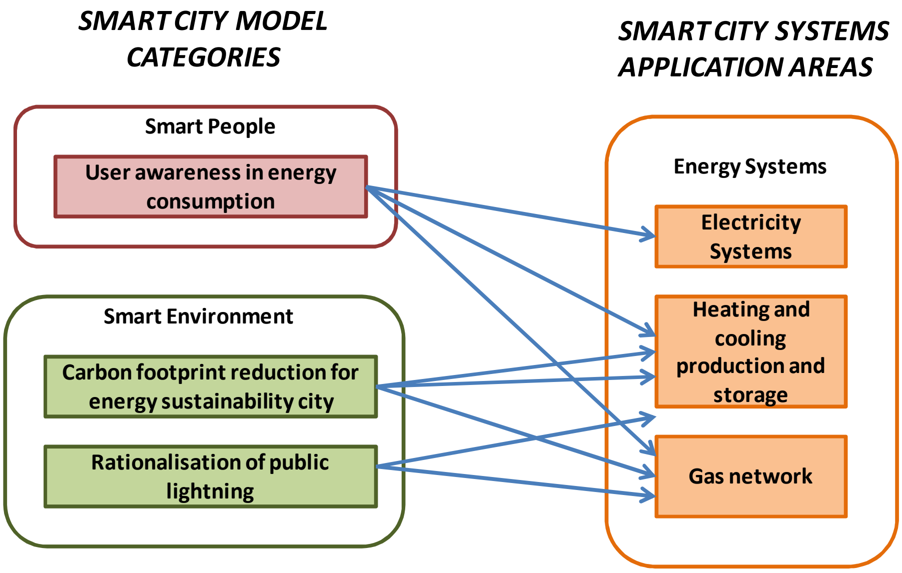


**Figure 12: Relation between categories of the Smart City model and the Energy Systems application area of the Smart City system**

## 4.2.3 People Involvement

People Involvement is a broad category focused on human behaviour and communication. For example by offering people ways to influence the urban planning process, sharing knowledge and awareness, as well as decision making situations and security. The key question is: what ICT solutions inhabitants of the neighbourhood will need and result in the improvement of the energy efficiency of a neighbourhood.

- <u>Public participation:</u> all issues related to increasing the commitment and participation of citizens towards energy efficiency goals and initiatives.
- <u>Privacy:</u> all aspects related to privacy protection of neighbourhoods habitants.
- <u>Energy Consumption behaviour</u>: all aspects related to the identification of energy consumption patterns of neighbourhood habitants in order to improve people behaviour towards energy efficiency.

The following diagram shows the relation between the Smart City model categories and the People Involvement application area and sub-areas of the Smart City systems.

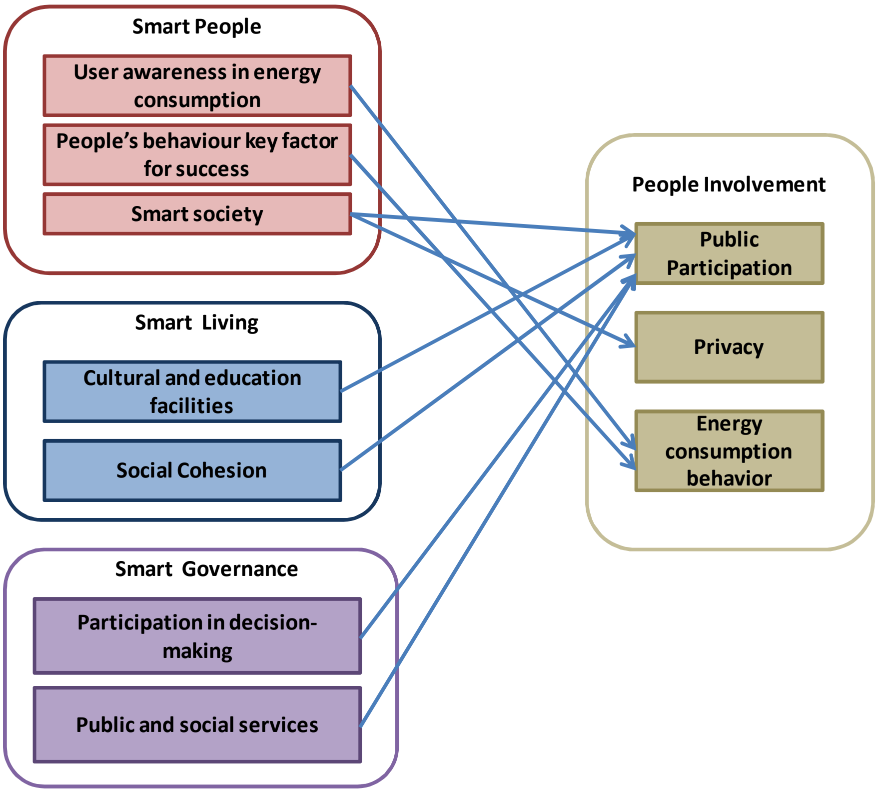


**Figure 13: Relation between Smart City model categories and the People Involvement application area of the Smart City system**

### 4.2.4 Holistic Urban District Systems

This is the high level system consisting of all sub-systems of a neighbourhood and how they are connected to each other and planned as an entire system. One main target is to minimise partial/sub-optimisation of individual systems, since it has effects to other energy systems in the same neighbourhood). This is the whole entity of neighbourhood systems which contribute together to maximised energy efficiency at the neighbourhood level.

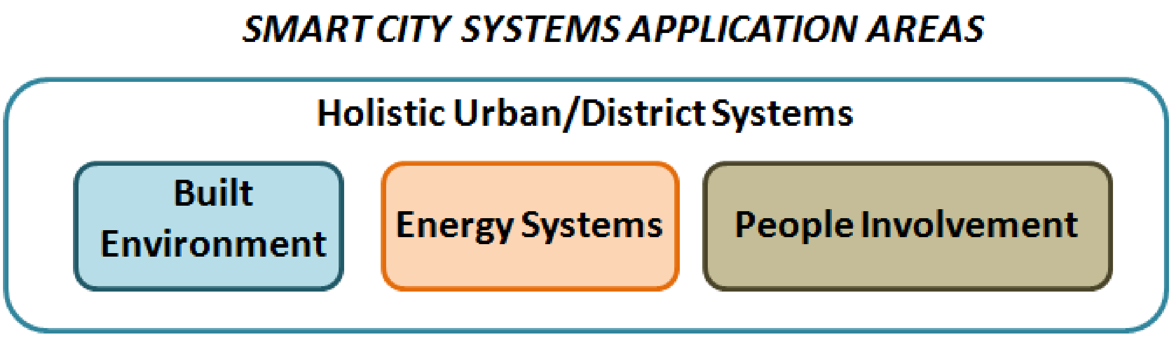


**Figure 14: The Holistic Urban/District system category integrates all the Smart City system application area in an holistic manner**

## 4.3 The Smart City System Scoping Matrix

The ICT key research topics (Technology Areas) and Smart City system application areas and more specifically their intersection extend the scope of ICT4E2B project towards energy efficient Smart City systems. It is helpful to adopt a matrix form (
Figure 15) to visualize and organize the scope. It is important to underline that this approach includes two different taxonomies, technology (matrix rows) and application areas (matrix columns), and the added value lies in evaluating the intersection of the rows and columns as it will be done in the following section by providing some concrete examples. The elaboration of this matrix has been done in parallel with IREEN project where it was also necessary and useful to start from the Smart City model to elaborate the application areas of the energy efficient urban and rural neighbourhood. Clearly the resulting extension for ICT4E2B Forum towards the Smart City system maintains its main focus on buildings, while in IREEN the focus is much broader by including all aspects of an energy efficient neighbourhood, this led to different technology areas, but also considered transport related aspects.

| Technology Areas – Integration technologies | Application Areas – Smart City Systems | Built environment | | | | Energy systems | | | People involvement | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Holistic urban/district systems | Buildings | Public spaces & lighting | Waste management | Water management | Electricity systems | Heating & cooling systems | Gas systems | Public participation | Privacy | Energy consumption behaviour |
| **Tool for EE design and production management** | | | | | | | | | | | |
| Design | | | | | | | | | | | |
| Production Management | | | | | | | | | | | |
| Modelling | | | | | | | | | | | |
| Performance Estimation | | | | | | | | | | | |
| **Intelligent Control** | | | | | | | | | | | |
| Automation & Control | | | | | | | | | | | |
| Monitoring | | | | | | | | | | | |
| Quality of Service | | | | | | | | | | | |
| Wireless Sensor Networks | | | | | | | | | | | |
| **User awareness and decision support** | | | | | | | | | | | |
| Performance Management | | | | | | | | | | | |
| Visualisation of Energy Use | | | | | | | | | | | |
| Behavioural Change | | | | | | | | | | | |
| **Energy Management and trading** | | | | | | | | | | | |
| Building Energy Management | | | | | | | | | | | |
| District Energy Management | | | | | | | | | | | |
| Smart Grids and the Building Environment | | | | | | | | | | | |
| Process Integration | | | | | | | | | | | |
| System Integration | | | | | | | | | | | |
| Interoperability & Standards | | | | | | | | | | | |
| Knowledge Sharing | | | | | | | | | | | |
| Virtualisation of the Built Environment | | | | | | | | | | | |

**Figure 15: The matrix describing the extension of ICT4E2B Forum scope towards Smart City systems.**

# 4.4 Technology Areas Applied to Smart City System Application Areas

***The purpose of this section is to provide some concrete examples of technology areas and sub-areas (rows of the matrix in Figure 15) applied to Smart City system application areas and sub-areas (columns of the matrix in Figure 15) in order to evaluate the extension of the ICT4E2B scope towards energy efficient Smart City systems.***

The following paragraphs are organized by technology area, then technology sub-areas each addressing a specific application areas and sub-areas.

## 4.4.1 Tool for EE design and Production Management

### 4.4.1.1 Design

4.4.1.1.1 Holistic District/Urban system

- Holistic optimization of the interactions between building and district/urban interface subsystems.
- ICT platforms to facilitate sharing and integration of evolving design information with district/city information sources and stakeholders.
- Integrate requirements from Cities green action plans into building design requirements.
- Interoperability between district planning tools and databases with building design tools.

4.4.1.1.2 Built environment

*Waste management - Water management:* New design processes and collaboration forms to integrate building and district water and waste systems design process. Design of connections to district or building collection systems.

4.4.1.1.3 Energy Systems

*Electricity systems - Heating and cooling systems - Gas systems:* Information and decision support system for optimizing the use of energy beyond the buildings. Systems to support a neighborhood-aware design taking into account connection to energy networks

### 4.4.1.2 Production management

4.4.1.2.1 Holistic District/Urban system

*Visualization and decision support* – ICTs should also proactively suggest options for site management as, e.g., virtual planning of construction site logistics considering neighborhood buildings.

4.4.1.2.2 Built environment

*Waste management:* Integrate construction site waste management with city waste management.

### 4.4.1.3 Modeling

4.4.1.3.1 Holistic urban/district systems

- Standardized data models (ontologies) of catalogue contents, in the context of building/district/urban sub-systems interfaces, regarding especially energy related attributes. Catalogues of materials and components to support the design of these subsystems, e.g., waste collection system, district heating, electric vehicle recharging points, etc
- New model based tools for improved energy efficiency through holistic optimization using integrated information at building, district and urban level, through a common ontology.
- Tools for modeling existing buildings & facilities for retrofitting design e.g. by scanning.

### 4.4.1.4 Performance estimation

4.4.1.4.1 Holistic District/Urban system

- Holistic simulators of complex systems such as buildings interacting with energy systems and infrastructures. Procedures and test cases for certifying software tools.
- Simulation based systems for refining requirements for highly interdependent complex systems and for validating the contributions of different subsystems to the overall energy performance in areas like complex office or public buildings and major infrastructures.

## 4.4.2 Intelligent Control

### 4.4.2.1 Automation & Control

Automation & control is a key technology for a functioning smart city and its subsystems. In cities of today it's a core technology for the built environment and energy systems. The smart city of the future poses even more application areas for automation due to the increase of system integration and call for increased energy efficiency.

4.4.2.1.1 Holistic Urban/District System

- Systems to automate and control in an holistic manner all the neighbourhood system.

4.4.2.1.2 Built Environment

- *Buildings:* intelligent network of electronic devices designed to monitor and coordinate the mechanical, electronics, and lighting systems in the neighborhood buildings.
- *Public spaces and lightning:* automation systems to optimize the lightning of public spaces, for example by lowering the level of the public lightning if no occupancy is detected at a certain moment in a specific street.
- *Waste management:* automated waste collection system to distribute waste to a centralized processing facility by using robotic rail containers.
- *Water management:* automated systems for softening and water purification in an optimized manner.

4.4.2.1.3 Energy Systems

- *Electricity system:* extension of intelligent control over electrical power grid functions to the distribution level and beyond. It is related to distribution automation that can be enabled via the smart grid.
- *Heating and cooling systems:* district heating and cooling provide great opportunities for efficient energy use and low-cost air-conditioning. Automation systems to supply control solutions for the district heating requirements: to match any nominal pressure, regardless of whether water or steam is used as the energy transfer fluid, whether the consumers are connected directly or indirectly, or whether the domestic hot water is heated in a storage tank, tank charging or instantaneous water heating system.
- *Gas system:* automation systems to dramatically increase the accuracy, efficiency, safety, and productivity of natural gas operations.

### 4.4.2.2 Monitoring

For improvement in operation of any system one has to know the current situation and if applied actions had the desired effect. Monitoring delivers this information and is applicable to all the areas of smart city systems. Despite the necessity of monitoring means has to be found to protect the privacy of individuals.

4.4.2.2.1 Holistic Urban/District System

Automation systems to monitor energy consumption of various neighborhood components in order to optimize them in a global manner.

4.4.2.2.2 Built Environment

- *Buildings:* systems to track the performance of a building's mechanical and electrical *systems* is essential for energy savings with integration at neighborhood level.
- *Public spaces and lightning:* systems to monitor the public lightning and reduce power consumption due to improved control of each individual street light.
- *Waste management:* system to monitor the waste production in a certain area to optimize its collection.
- *Water management:* system to monitor the water production and purification in a certain area in order to optimize its production.

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4.4.2.2.3 Energy Systems

- *Electricity System – Heating and cooling systems – Gas sytems:* systems to monitor electricity consumption – heating and cooling systems – gas systems at neighborhood level to improve the corresponding management

4.4.2.2.4 People Involvement

- *Public Participation:* semantic application to measure the relevance of energy-efficiency related topics discussed on social networks
- *Privacy - Energy consumption behavior:* system to analyze big-data (for example social-network data) to model the user behavior and optimize the corresponding energy systems. In this procedure the privacy of users must be protected

### 4.4.2.3 Quality of Service

Quality of service is of importance when information is exchanged electronically, which is applicable to any smart city area. Increased digitalization and automation of city services implies a risk in terms of security, safety and privacy that has to be addressed. The functionality of the system has to be protected and information leakage prevented.

#### 4.4.2.3.1 Holistic Urban/District System

ICT tools for diagnostic and renovation of existing buildings and infrastructures by considering their integration in the neighborhood environment

#### 4.4.2.3.2 Built Environment

- *Buildings:* ICT tools for diagnostic and renovation of existing buildings and neighborhood infrastructures
- *Public spaces and public lightning:* system that calculates the priority of various street lighting systems (for example depending on the occupancy) to optimize energy consumption in public lightning
- *Waste management:* ICT tools for diagnostic of correct functioning of waste compacting system
- *Water management :* ICT tools for detecting faults in water distribution system

#### 4.4.2.3.3 Energy Systems

*Electricity system - Heating and cooling system - Gas system:* self-diagnosis systems, sensors and communication protocols to be used in error detection for electricity distribution systems, heating and cooling systems and gas systems.

#### 4.4.2.3.4 People Involvement

- *Public participation:* technologies to guarantee a certain level of performance to the data flow of energy consumption data displayed in public places within the neighbourhood to increase people awareness
- *Privacy - Energy consumption behavior:* protocols to guarantee availability, reliability, privacy, security and safety for the analysis of big-data to extract user energy behavior

### 4.4.2.4 Wireless Sensor Networks

Wireless sensor networks provide the means of data collection with low installation cost. A downside with wireless communication is that it is more sensible to disturbances (intentional or not) and therefore less suitable for critical applications. However, there are application scenarios in every area of the smart city where low cost data collection and actuation is needed that are not safety critical.

#### 4.4.2.4.1 Holistic Urban/District System

Spatially distributed autonomous wireless sensors to monitor the energy consumption of various neighbourhood components in an holistic manner

#### 4.4.2.4.2 Built Environment

- *Buildings:* processes for designing the topology of a network of sensors in order to detect and integrate each new building or each new energy generation unit in the district energy network

- *Public spaces and lightning:* urban network, where sensors (nodes) are coupled to the lamp posts or lighting points in order to control the control the lighting for these points, and capture important information from diagnostics, operation and failures
- *Waste management:* wireless sensor to detect the level of filling of waste containers in order to optimize their management
- *Water management:* design of sensor network for optimal management of water resources within the neighborhood

4.4.2.4.3 <u>Energy Systems</u>

- *Electricity systems:* development of self- powered wireless sensors for monitoring the electric power grid
- *Heating and cooling systems - Gas systems:* wireless sensors to monitor heating and cooling systems or gas networks for efficient operation and predictive maintenance in order to early detect deviations from specified parameters that can cause expensive repairs and downtime.

4.4.2.4.4 <u>People Involvement</u>

- *Public participation:* wireless sensor to measure energy consumption in various neighborhood infrastructures to be displayed to inhabitants to increase their awareness
- *Privacy - Energy Consumption behavior:* sensors to measure the energy consumption of neighborhood habitants in order to model their energy behavior by preserving their privacy

## 4.4.3 User Awareness and Decision Support

### 4.4.3.1 Performance Management

4.4.3.1.1 <u>Holistic District/Urban system</u>

Models and methods to assess and visualize ICT solution impacts on the whole city energy consumption.

4.4.3.1.2 <u>Built environment</u>

- *Buildings:* Data-mining techniques to analyze and extract patterns from Building Management System logging data
- *Waste management – Water management:* Models and methodologies for analyzing and assess the energy saving provided by management of waste and water by innovative automation and control systems

4.4.3.1.3 <u>Energy Systems</u>

*Heating and cooling systems:* Assess the energy saving provided by controlling heat energy use in the neighborhood by exploiting the weather forecast

4.4.3.1.4 <u>People involvement</u>

- *Public participation:* models and methods to assess the energy saving provided by a energy efficiency campaign carried by social-network media

- *Energy consumption behavior:* data-mining of social-network data in order to extract the effectiveness and popularity of a certain energy efficiency initiative carried out by social-network media within the city

### 4.4.3.2 Visualization of energy use

#### 4.4.3.2.1 Holistic urban/district systems

Development of information process strategies to aggregate and visualize in a simple and easy-to-understand manner the energy performance data of the whole city

#### 4.4.3.2.2 Built environment

- *Building:* At building level, a pre-existent BEMS (Building Energy Management System) controls heating and cooling of common areas / services of the building (elevators, common lightning,..). A middleware platform system integrates information at home level (HEMS / smart meters), building and condominium level (BEMS). The platform also makes a data harmonization/intelligence of electrical consumption categories which are showed on a dashboard / control panel (a detail of each apartment can be displayed or not depending on the disclosure premises approved by the neighbors).
- *Water management:* analysis of water consumption data and extraction of consumption patterns to be further used by water service providers; this analysis will provide better knowledge of consumers habits and will indicate where potential water savings are possible.

#### 4.4.3.2.3 Energy Systems

*Electricity – Heating and Cooling – Gas network:* Development of a system that is able to help plan and manage local energy generation, storage and trading by creating a dynamic system simulation to help cities to specify, design, finance, install and operate demand side participation solutions based on a de-centralized model of energy generation, heat storage, cooling and associated capacity trading system within an urban environment - i.e. a virtual power plant. The tool will be used by a municipality or other urban organization that will make decisions about the commercial and engineering viability of an energy project or intervention.

#### 4.4.3.2.4 People involvement

*Public Participation:* Development of a system to create awareness of individual Carbon Footprint directly related to the amount of energy used in everyday life of city habitants. In order to participate in the awareness action, the habitants will download an application for mobile device to get and store information related to the Carbon Footprint associated with the activities that they are carrying out, as well as the associated energy consumption. The acquisition and transfer of information will be achieved through the installation of different embedded systems inside the public and private district buildings, the personal or public means of transport, etc. such as RFID tags.

### 4.4.3.3 Behavioral change

#### 4.4.3.3.1 Building Infrastructure - Energy systems

*Buildings:* Development of Energy Management System (HEMS) installed in the city habitants homes. This system provides holistic power management for houses. The system provides an integrated home security system; lighting; heating/cooling, appliances and other equipment to take a whole house approach to energy efficiency. It also takes in to account if an house is fitted with solar panels and/or solar hot water system. The user has access to current and historic data in order to monitor the energy usage and to real time data of current use. The system is able to use the system to compare the energy consumption to that of others in the city (by selecting for example similar property / occupancy types). Moreover, the data is aggregated and is made available to the municipality responsible.

4.4.3.3.2 People Involvement

*Public Participation – Energy consumption behavior:* Development of social network solutions to connect city habitants with the aim of providing interactive and shared information about good energy efficiency practices and compare energy consumption between different habitants by preserving privacy,

## 4.4.4 Energy Management

### 4.4.4.1 Building Energy Management

Buildings are seen as integral part of the future Smart Cities and not as isolated entities. In futuristic scenarios, buildings are autonomous and cooperative, while they try to optimize their energy management including trading energy resources online. Newer buildings will integrate advanced capabilities already by the design phase. However, for older buildings, and in order to be able to participate in energy management scenarios, retrofitting is needed. The latter implies high costs and effort, however the usage of intelligent monitoring and control devices as add-ons, that operate wirelessly is expected to provide some help.

4.4.4.1.1 Holistic urban/district systems

Energy Management and Trading technologies could provide a good view with respect to planning in new urban/district systems. Weak points in energy distribution network could be identified (by simulation, modelling, etc.) and more holistic planning could be done. For instance the respective technical infrastructure could be set-up to accommodate industrial buildings, commercial centres etc.

4.4.4.1.2 Built environment

- *Buildings:* As buildings will be equipped with intelligent networked devices and systems, they are expected to autonomously manage their resources optimally and according to their needs. Additionally buildings will be part of a larger ecosystem and hence cooperate with other entities e.g. other buildings, etc. to manage their energy footprint according to global needs e.g. those of a smart city. Adjustment of energy production or consumption on buildings may be done automatically and scenarios are expected to emerge that will offer business benefits in doing so. Scenarios and business models will need to be expanded to cover additional emerging innovations.
- *Public spaces & lighting:* Future users of spaces e.g. company rooms, will be able to customize their working place to their needs, while energy adjustments (e.g. heating, lighting etc.) will be done automatically based on the user's and building's needs. Further investigations are needed to the pervasive technologies and their coupling with the energy management approaches.

4.4.4.1.3 Energy systems

- *Electricity systems:* Depending on the sophistication of energy management as well as the services that they will need to provide to their inhabitants, the buildings will have a profound impact on the way energy systems are designed and operated. As the latter will become increasingly complex in the effort to satisfy multiple requirements and enable new approaches, more research should be targeting design, planning, operation of future multi-faceted energy systems as well as migration of existing ones to the Smart Grid envisioned.

- *Heating & cooling systems:* Heating and cooling in the buildings will need to be integrated with all other systems and be commonly managed. This implies a common information infrastructure as well as the development of tools and applications to monitor and manage them within a building and also among larger areas (e.g. industrial facilities).
- *Gas systems:* Gas systems can act as flexible storage of a surplus of electric power (Power to Gas), and when needed the stored gas can be converted into power, heat etc. Therefore gas systems can be used for energy balancing and hence empower better energy management at building level. Hence, they are seen as an integral part of energy-related systems including CHP etc. that will need to be managed within the systems of a building. Tools that will assess promptly the available storage resources, energy prices and energy needs at building and enterprise level will be needed to take fully-informative decisions at facility management level.

4.4.4.1.4 People involvement

- *Privacy:* As people in the future may be able to fully customize parts of the building to their needs, privacy considerations arise with respect to the information that need to be exchanged in order to guarantee effective energy services within the future buildings. Security, trust and privacy are issues that need to be investigated in order to embed them in the envisioned interactions between people (and their proxy devices) and buildings.
- *Energy consumption behaviour:* Future buildings are expected to automatically tailor their energy behaviour to their needs as well as those of people using their spaces. Information exchange may lead to better energy efficiency depending also on the trade-offs the user is willing to make and the comfort level s/he can accept. Direct control on the building's information and management resources may also enable the users to further assist buildings reach their energy efficiency goals even in simple scenarios e.g. the users turn-off the lights remotely, or enable heating in a meeting room shortly before the meeting starts etc.

### 4.4.4.2 District Energy Management

4.4.4.2.1 Holistic urban/district systems

Holistic urban/district system planning, operation and migration from current systems will benefit from energy management and trading technologies. Future cities are expected to be managed in holistic ways, while their data will flow in real-time and be analysed e.g. for energy efficiency, $CO_2$ impact, regulation compliance etc.

4.4.4.2.2 Built environment

- *Buildings:* Integration of building energy management systems with fine-grained control. Additionally the capability to exchange information with external services and stakeholders will enable them to better participate in district energy management schemes. Compliance to the district's regulations and real-time reporting of energy related aspects is of interest.
- *Public spaces & lighting:* Public spaces and lighting will need to be managed according to district's needs. Additionally they could act as flexible infrastructures (where possible) and enable the stakeholders e.g. public authorities to adjust their usage for energy efficiency and potentially other benefits [8].

4.4.4.2.3 Energy systems

- *Electricity systems:* Electricity systems could be interconnected and exchange information over common platforms. Additionally dynamic energy trading could be enabled which would allow the optimal usage of energy production and consumption within the district to be handled via financial transactions on the market.
- *Heating & cooling systems:* Heating and cooling systems could play a role in energy markets depending on their capabilities for self-control, and trade the available flexibility [8] in energy marketplaces; the latter could enable new roles for traditional infrastructure owners within a district.

4.4.4.2.4 People involvement

- *Privacy:* Privacy may be an issue, especially when considering potential data that needs to be exchanged at district level. Privacy preserving approaches that enable districts to manage their energy while considering business and user privacy requirements need to be investigated.
- *Energy consumption behaviour:* Energy awareness as well as active participation of citizens can enable to better understand and manage energy at district level. Applications that clearly depict the energy efficiency measures taken by people and the impact they have on their districts may further motivate them to be energy efficient [10] and assist the district to achieve its environmental goals.

### 4.4.4.3 Smart Grids and the Built Environment

4.4.4.3.1 Holistic urban/district systems

The Smart Grids is going to have a profound effect on the built environment at urban/district systems. This is affecting design of future areas, by posing new requirements that they will have to consider and offer in order for smart grid visions to become a reality. Especially the capability of monitoring and managing aspects in the built environment is expected to play key role.

4.4.4.3.2 Built environment

- *Buildings:* Buildings will be empowered by the smart grids and therefore models and innovative applications are needed to take advantage of the plethora of information that will be available. Smart buildings managing their energy footprint efficiently and communicating with the smart grid infrastructure will be able to assist the grid in its stability and in parallel provide future information on the energy they will need (which will help the smart grid plan and also dynamically adjust to short-term requirements).
- *Public spaces & lighting:* Networked embedded devices for monitoring and fine-grained control of lighting will enable more energy efficient management, and also allow the smartgrid to interact with them for the benefit of all stakeholders. Some examples on how the public lighting systems could be used in the smartgrid era are given in [8].

4.4.4.3.3 Energy systems

- *Electricity systems:* the combination of smartgrids and built environment with energy management and trading is profound. For instance based on energy trading, the smartgrid operators could get future information with respect to the behaviour of the users and buildings, which could be valuable for planning. This could enhance existing prediction efforts, which now can also be complemented not only with fine-grained data coming from all levels of the infrastructure (buildings, cars, public spaces etc.) but also assess the link between the higher level effects on the requirements that the grid will have to cover e.g. social events, etc.

- *Heating & cooling & gas systems:* The heating and cooling systems are seen as complementary within a smart grid and can help in the load balancing of the grid. Additionally new applications that will enable facility managers to better manage all of their energy infrastructure and provide detailed support for decisions is needed.

4.4.4.3.4 People involvement

- *Public participation:* Application that provide information to the people may lead to their active engagement to energy efficiency efforts. People also expect value added applications and services to emerge [10], and the combination of smart grid, and smart buildings via the energy management and trading technologies may provide it. New studies on involving the public and witnessing the effect of their involvement is needed.
- *Privacy:* Tools that will assess the privacy requirements and enable all stakeholders to respect them are needed. The acceptable trade-off between privacy and energy service offering as well as the transparency of information flow should be further investigated and built-in future smartgrid solutions.
- *Energy consumption behaviour:* People are willing to adjust their behaviour if this may help the environment, however the adjustments should be minimal and transparent to them. This implies that the underlying building systems should adjust to the user's behaviour, offer energy efficiency alternative solutions, and follow the most energy optimising strategy while still enabling the user to perform his everyday tasks within a building. The cooperation of people and buildings in the smart grid era is expected to lead to new innovative applications.

## 4.4.5 Integration

### 4.4.5.1 Process integration / System integration

4.4.5.1.1 Holistic District/Urban system

- Linking energy production and measuring parameters with other city processes (waste management and water management etc) to plan and adjust optimal use of resources.

### 4.4.5.2 Interoperability & Standards

4.4.5.2.1 Holistic urban/district systems

- Use of existing communication standards and technologies to enable efficient use of resources by means of ensuring that the necessary resources are dedicated to a given task, and not more than the necessary resources are used. This can be done by taking into account public demand (measuring it) of a given service, and adjusting service provision to the demand in a manner as real-time as possible.
- Sample standards may include using common citizen electronic ID systems for multiple city services (library, transport, health services, recreation, etc…)

### 4.4.5.3 Knowledge Sharing

#### 4.4.5.3.1 People Involvement

*Public Participation* – Integration of knowledge collected from citizens about many aspects of city life to identify trends, best practices, and to promote them among the whole population of the city.

# 5 Conclusions

In this report we have provided an up-to-date version of the REEB roadmap, the first CA roadmap that has been developed, by REEB project, in the field of ICT for Energy Efficiency in Buildings.

In addition, some considerations have been raised analysing the impact of ICT for Energy Efficiency at the emerging broader district or Smart Cities perspective. This addresses the activities of the IREEN Research Roadmap (ICT Roadmap for Energy Efficient Neighbourhoods) and guarantees the necessary interweaving and interoperability between the targeted domains of the two projects, i.e. buildings and districts.

Starting from this baseline we have performed an overview check of all the scientific works so far achieved or ongoing (Scientific Publications, keywords) in order to identify some new research keywords not considered inside REEB classification. In addition we also performed a check of the European Research Projects so far achieved or ongoing focused on ICT for Energy Efficiency in Buildings.

Following the findings of the previous analysis, that confirmed the validity of REEB main classification areas, and a deep review work performed by the project partners, we have provided an updated classification with minor changes in the topic structure. The areas that have been affected by slight modifications have been “Tools for integrated design and production”, “Energy management & trading”, “User Awareness and Decision Support” and “Integration Technologies” (this is under the greatest investigation), where we have inserted some new terms and merged together some redundant terms.

The great added value of the improvement work performed has been the formulation of a clear definition for each term in the classification,. Furthermore we have provided examples to show their potential impact in the ICT for Energy Efficient Buildings field.

Finally we envisioned the extension of ICT4E2B scope to Smart City systems by elaborating the Smart City Model towards an extended scope that can embrace the complexity of energy efficient districts and cities. The six Smart City areas have been further elaborated in five application areas and sub-areas to define the concept of energy efficient Smart City systems. The ICT key research topics and the Smart City system application areas and more specifically the intersection of these two taxonomies extend the scope of ICT4E2B project towards the Smart City systems: concrete examples of this procedure have been elaborated in the final section.

The final result is an updated classification of research topics on ICT for Energy Efficiency in Buildings, which support the following of the project:

- A detailed analysis of the state-of-the-art against the different identified topics (D1.2);
- A detailed analysis of research project against the different identified topics (D1.3);
- Identification of the application scenarios of the different ICT4EE research areas, following the given topic exemplification (D2.1);
- Definition of a prioritized gap analysis of the different research areas, identifying the efforts needs for each one (D2.2);

- A preliminary updated research roadmap for the different identified research topics of the REEB roadmap (D2.3);

- A shareable knowledge content of the research activities on the Energy Efficient Buildings field, furthermore revised and improved, that will be disseminated to the communities by the public portal (D4.2).

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