A COMPREHENSIVE VISION ON CARTOGRAPHY OF EU AND INTERNATIONAL RESEARCH INITIATIVES WITH RTD GAP ANALYSIS IN THE AREA OF ICT FOR ENERGY EFFICIENCY IN BUILDINGS

A. Hryshchenko, MEngSc, Researcher; a.hryshchenko@ucc.ie
K. Menzel, Professor, Dept. of Civil and Environmental Engineering, k.menzel@ucc.ie
N.U.I. University College Cork

ABSTRACT

This paper analyses the status of current researches in the area of Information and Communication Technologies (ICT) for the improvement of Energy Efficiency (EE) design and operation of buildings.
Currently, research and technology developers focus on different domains and sub-domains in the area of EE, such as the integration of renewable energy sources and related monitoring, simulation, and management software. In order to improve harmonisation between different Research and Technology Developments (RTD) including International and European research projects and scientific programs these activities need to be categorised and analysed. As a result of RTD gap analysis, the challenges, commonalities, deficits, and potentials for collaboration are identified contributing to the development of a "Scientific Road Map".
This paper focuses on development of a comprehensive vision on Cartography of recently completed, ongoing, and recently announced research European projects and International research initiatives for further implementation of its results in global vision of the REEB project [cf. http://www.ict-reeb.eu/index.html], and proposes a systematic categorization approach to identify gaps in the current research agenda in the area of IT for Energy in Buildings.
Our RTD Gap Analysis is based on a quantitative and qualitative categorization of the carefully selected RTD, specifying their common classification criteria.
During the REEB project, there are more than 270 projects worldwide were analysed, and five Main Classification Categories (MCC) were developed in order to categorise selected researching activities. During the project we've extracted and combined for statistic analysis and conclusion development the RTD-related information, i.e. location of the research (country), type of RTD developer(s) etc.
The proposed methodology is allowing the identification of deficits of the related research within the specified five Main Classification Categories. The detailed RTD gap analysis was developed together with comprehensive vision on cartography of EU and international research initiatives.

Keywords: information and communication technologies, energy efficiency, research and developments, RTD, categorization, gap analysis.

INTRODUCTION

While Europe and the world are facing very serious challenges – strict energy usage control and the development of new ideas and technologies for it – we cannot ignore the positive research and innovations tendency in ICT development cluster. Inspiration and novelty are key issues for the most of ongoing research activities of the last decade, thankfully due to efforts of the European Union, European researching organisations and EU-member states.

This RTD Gap Analysis identifies major challenges in:

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

This paper based on the REEB-research strategic roadmap (cf. [1]) is a blueprint for Europe to develop a world-class portfolio of affordable, clean, efficient and low-emission energy technologies. The cartography of European and International Research initiatives helps towards the realisation of such a blueprint.

2. SELECTION CRITERIA FOR RECENT KEY RESEARCH PROJECTS

The main approach of REEB project is to examine current research activities and best practices for ICT applications and tools which are relevant to energy efficiency in built environments, with emphasis on standardization initiatives and developed regulations. This provides a definition of common research points and a "Scientific Roadmap" for the implementation of actions related to ICT support of energy efficiency in the built environment and a strategy for information exchange and dissemination between all energy-related ICT projects, initiatives, and stakeholders within European Union.

Based on the focus and requirements of the REEB project, we initially defined three main areas which were suggested as a Key Selection Criteria, namely:

(I) Implementation of Information and Communication Technologies, to
(II) Control Energy Efficiency and Energy-Management, when
(III) Applied to Build Artefacts.

The methods for categorizing a group of research projects typically depend on a well specified set of attributes for each project, which facilitate the classification of these RTD within specific categories. We decided to use a "Bottom-Up" approach as an appropriate method for categorization process. This method essentially breaks down a whole number of selected RTD into separate groups of compositional categories. Each category then will be refined in more detail on the following sub-category levels until the complete specification of each RTD will satisfy the requirements on a logical basis. The aims of this task are: (1) to select the most appropriate characteristics of each selected RTD; (2) to find similar research targets/final products, and (3) to define these results as categories.

At the present, there are more than 270 projects worldwide were scanned, five Main Classification Categories (MCC) were developed as result of separate analysis and evaluation of selected RTD.

The names and numbering for the five MCC consolidated are:

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

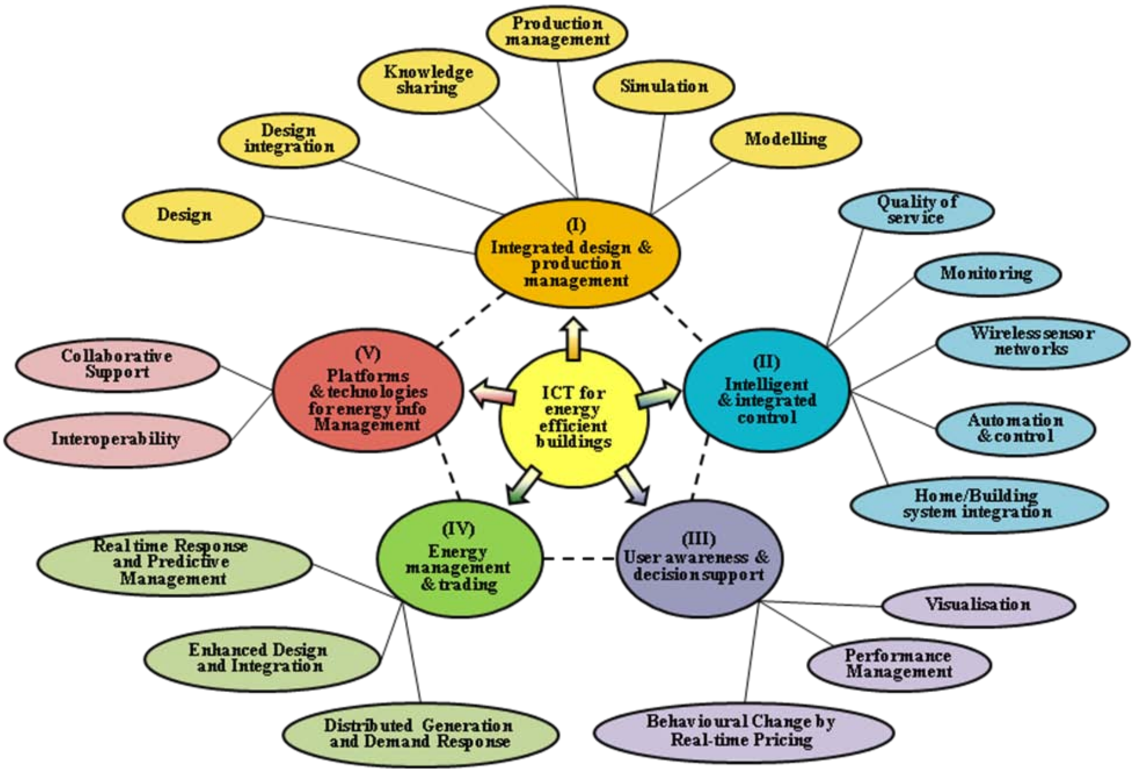

Figure 1. Graphical representation of the five Main Classification Categories and sub-categories

The overlapping issues and similarities are extracted during the analysis process. It is accepted that each single research project is unique because of its different developers and different approaches to specific problems and solutions.

This paper represents the **Quantitative** and **Qualitative** Gap Analysis of selected RTD per developed Main Classification Category (MCC) and related sub-categories, type and nature of research participants, including the research cartography analysis and recommendations separately for each of MCC.

3. APPROACH TO THE GAP ANALYSIS

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

- The **Quantitative** Gap Analysis is identifying the distribution of researching projects within the EU and worldwide by several major parameters. The resulting **Cartography** can be used towards the dissemination of European initiatives for blueprint of affordable, clean, efficient and low-emission energy technologies.
- After the detailed selection and deep analysis of those researching activities related to "ICT for Energy Efficiency (EE) in Buildings", a **Qualitative** RTD Gap Analysis was carried out. The aim was not only to describe the MCC and allocate RTD projects within these categories, but also to

identify and evaluate the weak/non-covered areas in each of the category.
- From the Qualitative and Quantitative analyses, the research challenges were defined. These identified challenges for each of MCC were evaluated and assessed against opportunities in ICT sector to develop the research gaps recovery.

4. CARTOGRAPHY OF EUROPEAN & INTERNATIONAL RESEARCH INITIATIVES AS A QUANTITATIVE ANALYSIS OF SELECTED RTD

The cartography process of EU and International RTDs, as a part of gap analysis, will help to:
- Reach an understanding of the global picture of current status of “ICT for building’s EE” research domain;
- Gain the consensus about a set of RTD’s results and further needs, as well as to define technologies and efforts required to satisfy those needs;
- Provide a mechanism to help forecast technology developments in the area of interest to REEB;
- Develop a framework to plan and coordinate research activities by RTD’s coordinating bodies.

On the first step of categorization and evaluation process it is necessary to identify and classify the providers of selected RTDs. This means to answer the questions “Who are they?” and “Where are they from?” It is possible to name those developers in terms of “Academic”, “Government”, “Public Organizations”, “Contractors”, “Suppliers” or “Others”. In order to narrow the scope of our analysis, the centre of attention is concentrated on the categories “Academic”, e.g. universities and different researching bodies. Any other research developers are subsequently named as “Others”. The distribution of research partners in domain of “ICT for EE in Buildings” per countries of European Union is presented on Figure 5 below.
As a first conclusion for cartography of European and International researches we can represent the distribution of the currently performed (as well as recently finished) researching activities per MCC, country of EU, together with an overall number of RTD performers (cf. Figures 2-6 below).

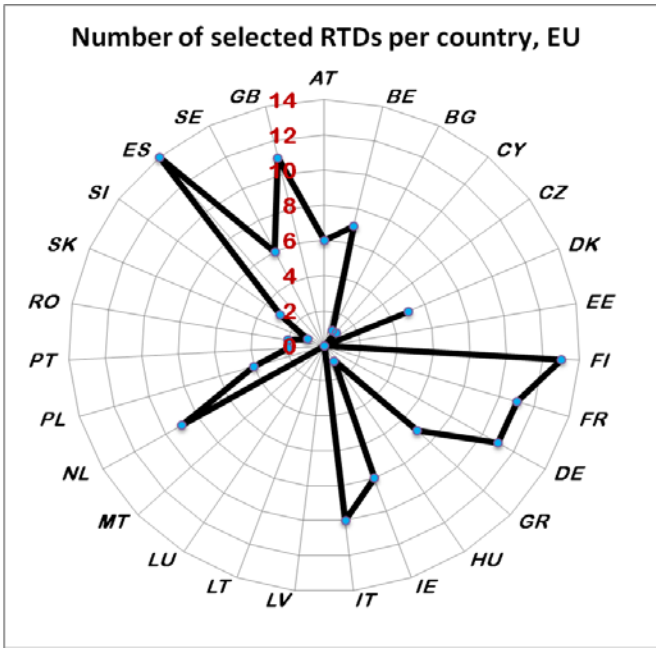

Figure 2 Distribution of selected RTD and their performers per country of EU

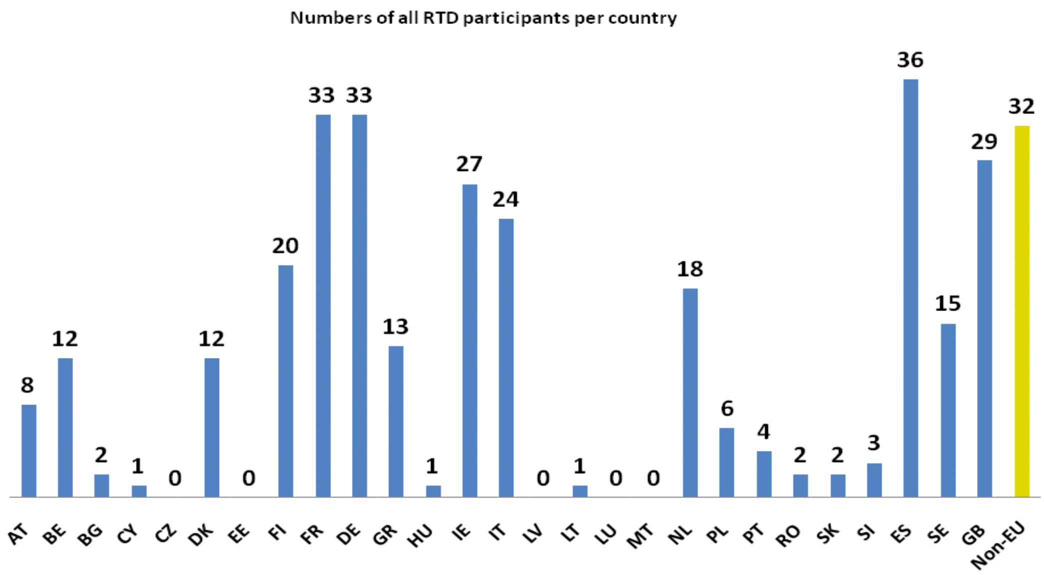

Figure 3 Number of all RTD participants per country

At this stage we should admit the situation of un-proportional distribution of REEB-related RTD developers per countries, while there are very limited number (or even absence) of research performers is identified in some countries (e.g. Latvia, Romania, Bulgaria) on the background of well-developing countries (e.g. Spain, France, GB, Finland).
The Figure 4 below represents the global picture of RTD participant's percentage distribution per countries of their location:

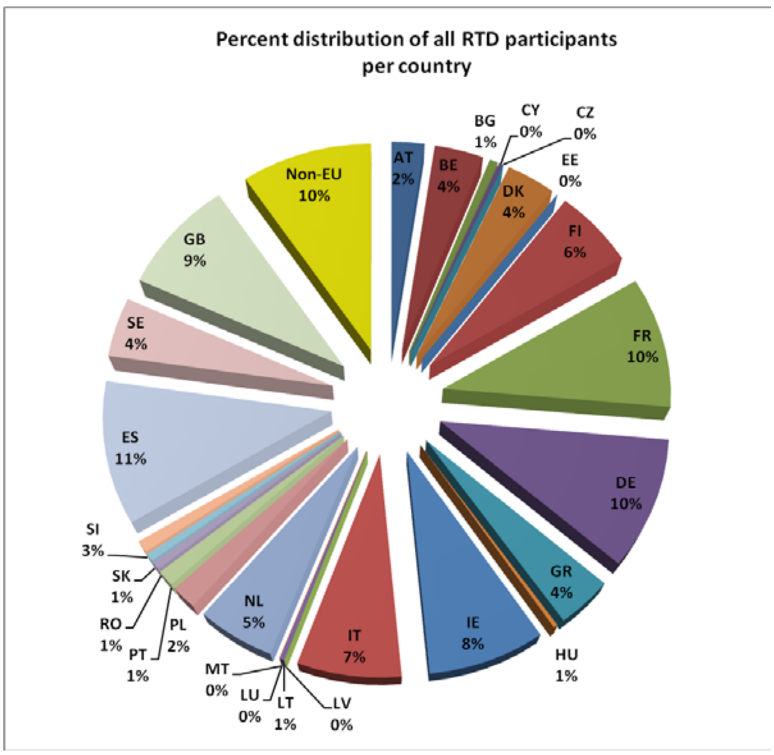

Figure 4 Percent distribution of all RTD participants per country

During the further deep analysis of selected researching activities we evaluated the distribution of the research participants (by the type of RTD developer – "Academic" or "Others") per countries of their location.

The following figure is presenting the results of this analysis:

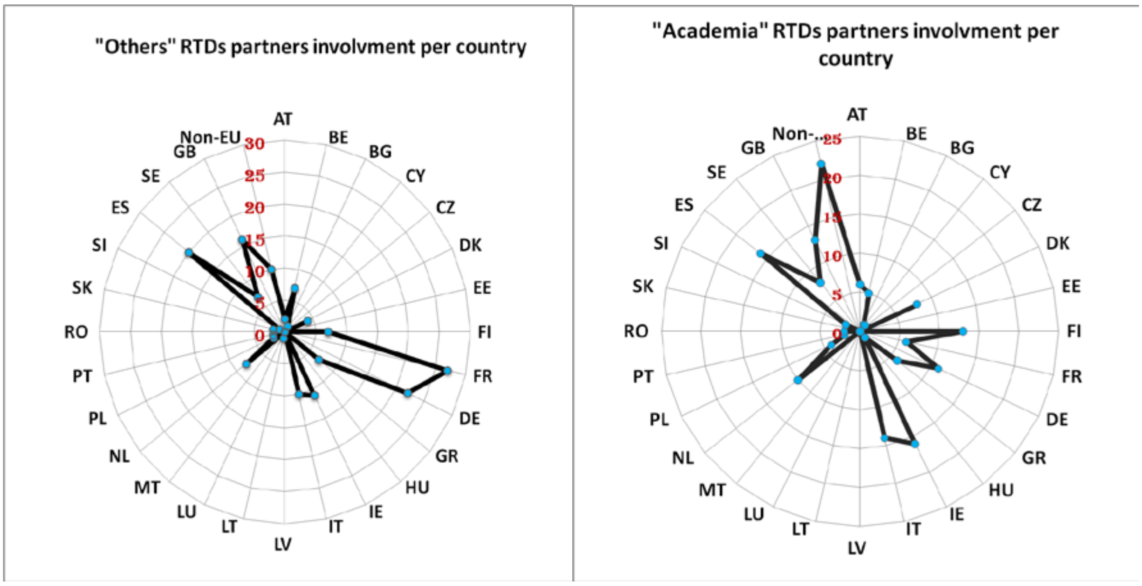

Figure 5 Distribution of RTD partners per country (non-EU included)

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

5. RTD QUALITATIVE GAP ANALYSIS

5.1 Distribution of Projects across the Main Classification Categories

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

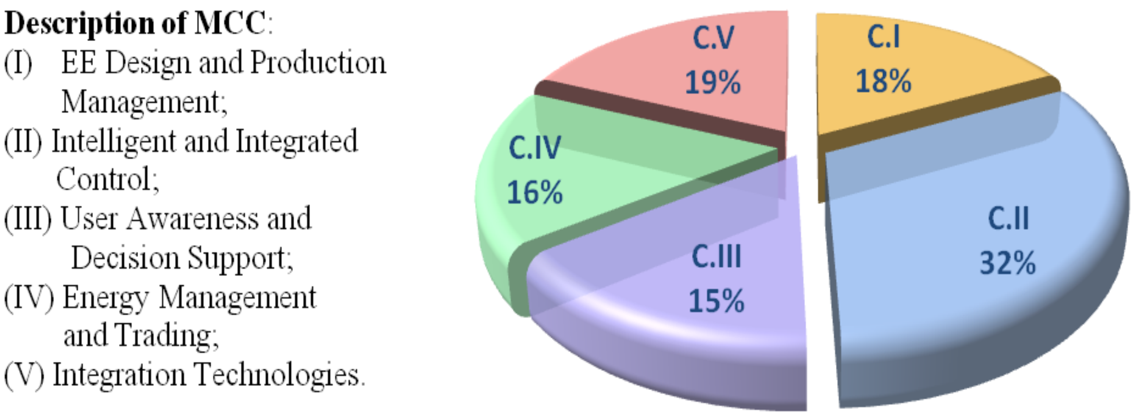

Figure 6 Total percentage distribution of selected RTD-workload per MCC I – V

5.2 The identification of research challenges

The Qualitative Gap Analysis provides an indication of the areas of interest moving researching activities forward. Also these are the areas analysed and used to develop a REEB road map. Future decisions about the direction of European research activities in the area of ICT for Energy-Efficiency in Buildings could be based on this analysis of aims and results of most recent and current projects which have been evaluated during the work of REEB project. The following proposed research areas are identified as a summary of the REEB gap analysis per MCC:

(MCC I) EE DESIGN AND PRODUCTION MANAGEMENT, INCLUDING:

- **Design Profiles / Archetypes:** There is a need to better support energy simulation in early design stages.
- **Design Integration through Standards:** A need for standardized models to exchange and manage 'energy-related' information in BIM was identified. Furthermore, we have identified the need for advanced simulation tools, allowing the modelling of renewable energy sources, advanced HVAC components, passive and active storage capacities, etc.
- **Knowledge Sharing:** amongst the different stakeholders, especially with SME, was identified as important research task**.**
- **Decentralised Information Management and Supply Chain Management (SCM):** Energy systems in buildings use many pre-manufactured components. A need for decentralised information management to better support SCM, assembly, and maintenance was identified. R&D is also required to support "just-in-sequence" delivery in renovation projects in "Urban Settings". These activities are 'secondary' support actions.
- The identification of explicitly efficient **architectural and engineering approaches** from design, production, installation, and to the service/support techniques, should be taken as a main targets of future research projects. For example, development of a novel CAD tool which supports design of a wireless SI with respect to radio propagation, node placement, localisation and reliability as well as supporting simplicity of installation on site, will provide significant positive impact on energy efficiency in buildings. Furthermore design of a BMS architecture that will support combination of services with managed operations across several administrative (e.g. end-user, BMS-operator, owner of building) and business domains (e.g. service providers/suppliers, facility managers, network operators), will cover existing industrial demand for dynamic, re-configurable building service architectures.

(MCC II) INTELLIGENT AND INTEGRATED CONTROL, INCLUDING:

- **Integrated Management of Monitoring Data:** A deficit for advanced concepts for 'Multi-dimensional Bulk Data Management and Data Analysis' was identified and needs to be addressed in future research..
- **Middleware:** New middleware to facilitate interoperability amongst different devices will be needed.
- Adoption of common, **open architecture and advanced control protocols** for communication platforms still provides a big challenge for further investigation. Development of power-efficient network protocol infrastructures which are suitable for supporting the middleware will greatly improve efficiency of energy management systems and dynamic service compositions.
- **Innovative Wireless Sensing, Metering Components:** A need for robust energy management/energy harvesting and customised packaging was identified, to allow 'long-term', maintenance free operation in buildings. New hardware and functionalities will require more powerful firmware, which should evolve from proprietary OS to standardised ones to support easy, plug & play installation.

- **Systems Integration / Communication Networks:** Additional options to support new communication features will have to be added to existing communication devices. Some examples of new features:
  - ✓ Wide band Programmable Logic Controller (PLC) interfaces;
  - ✓ New Virtual Private Network (VPN) embedded interfaces;
  - ✓ Low Power communication interfaces.

- **Development Tools:** As wireless components are penetrating the market, new development tools for wireless networks will be needed, such as Integrated Development Environments (IDEs) to allow easy, plug & play installation.
- It is also necessary to pay additional attention to improvement of building **Sensing Infrastructures (SI)** by development of seamless and dynamic end-to-end network compositions and service operations based on a wide range of components from sensor nodes, to Wi-Fi devices, RFID tags and readers. The development of a flexible wireless SI with modern, miniaturised (but still automatic) sensor nodes (e.g. embedded into the building fabric), will greatly improve self-configuration, self-optimising, and self-healing of such an infrastructure. This includes development and analysis of effective miniaturisation and packaging approaches for next generation of sensor nodes to allow embedding into the building fabric and investigation of effective node energy management techniques.

(MCC III) USER AWARENESS AND DECISION SUPPORT, INCLUDING:

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

(MCC IV) ENERGY MANAGEMENT AND TRADING, INCLUDING:

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

intuitive, self-learning and reporting, so that the system's self-motivated actions will lead to improved building performance.

(MCC V) INTEGRATION TECHNOLOGIES, INCLUDING:

- **New System Roles:** As new business models will appear, the privileges and constraints for different actors will need to be specified (in agreement with governance bodies).
- **Business Work Flows:** The development of new data exchange policies amongst different stakeholders was identified as a future R&D activity.
- There exists a huge business potential in development of robust, user driven decision support **applications for BMS and energy management**, providing energy calculations, simulation and visualisation. These applications should provide users with easily understandable energy performance indicators, which will help consumers to make intelligence led decisions.

6. INTEGRATION OF RTD RESULTS

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

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

As seen on figure 7 below, the practical RTD results implementation trend can be observed through comparing of proportional MCC distribution in Research and Technology Development (RTD) and Best Practice (BP, i.e. physically implemented working systems and buildings) analysis results for the same categories. In categories II (Intelligent & integrated control), III (User awareness & decision support), IV (Energy management & trading) & V (Integration Technologies) there is a small deficit between the RTD and BP. Category I (EE design & production management) is particularly well developed.

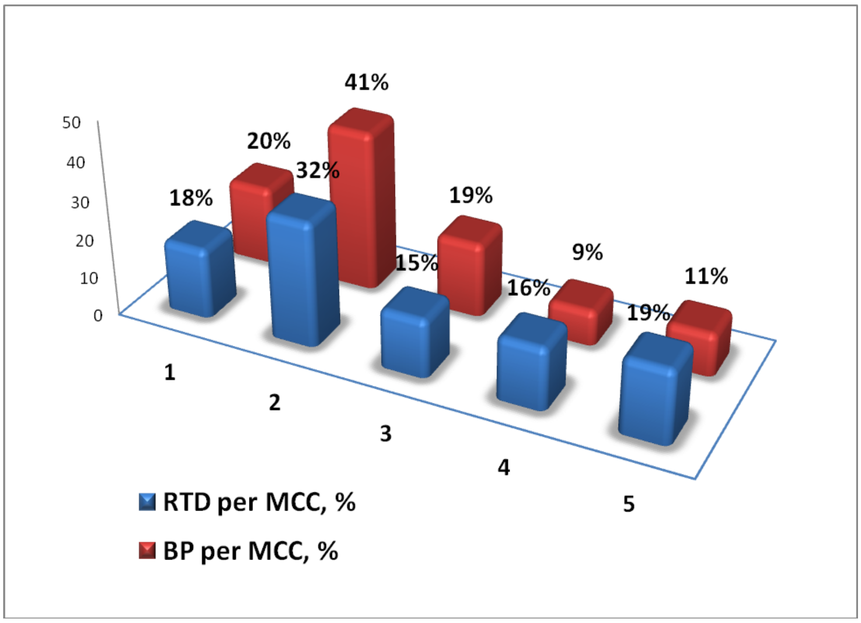

Figure 7 Comparison of RTD and BP evaluation results

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

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

7. POTENTIALS FOR FUTURE CONSOLIDATION OF EUROPEAN RESEARCH ACTIVITIES

Currently European research projects are not entirely interactive between different EU countries, and only slightly better between different institutes within individual countries. This can be explained by many different (sometimes narrow) specializations of researching institutes, exact subjects of projects performed, languages and distance barriers, and from time to time by commercial interests of industrial participants of those RTD. Fortunately in the course of the influence of innovative ICT, it is becoming more common and easier for research projects to be initiated by research developers groups which are based in multiple European countries. Therefore effective strategy for consolidation of the interrelated projects can be further implemented due to easy access to project-related information on various platforms, avoidance of repetitiveness in RTD topics and strict consolidated governance/control of RTD by EC and other research-funding bodies.

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

The end of the first decade of XXI century it has become more important to push through the barriers for innovation strategies and further improve collaboration in basic research. This approach will support the path for world-class innovation for EU-based RTD.

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