Gap Analysis

Research and Technology Development Activities

Gap Analysis of Research and Technology Development Activities

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

Outlining the RTD activities

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

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

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

The Challenges and Objectives of Gap Analysis

<u>This RTD Gap Analysis identifies major challenges in</u>:

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

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

The specific objectives are:

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

Approach to the Gap Analysis

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

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

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

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

Distribution of Projects across MCC

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

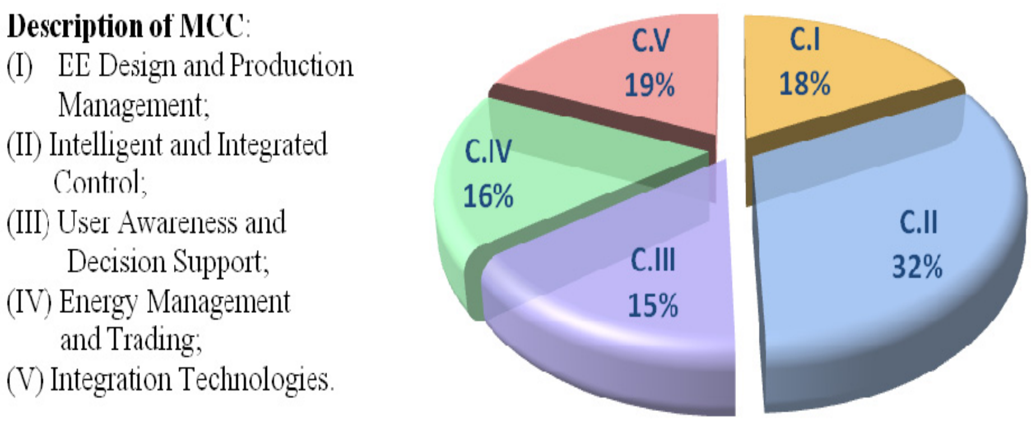

Figure 14: Total percentage distribution of selected RTD per MCC I – V

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

This category includes RTD activities focusing on the development of:

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

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

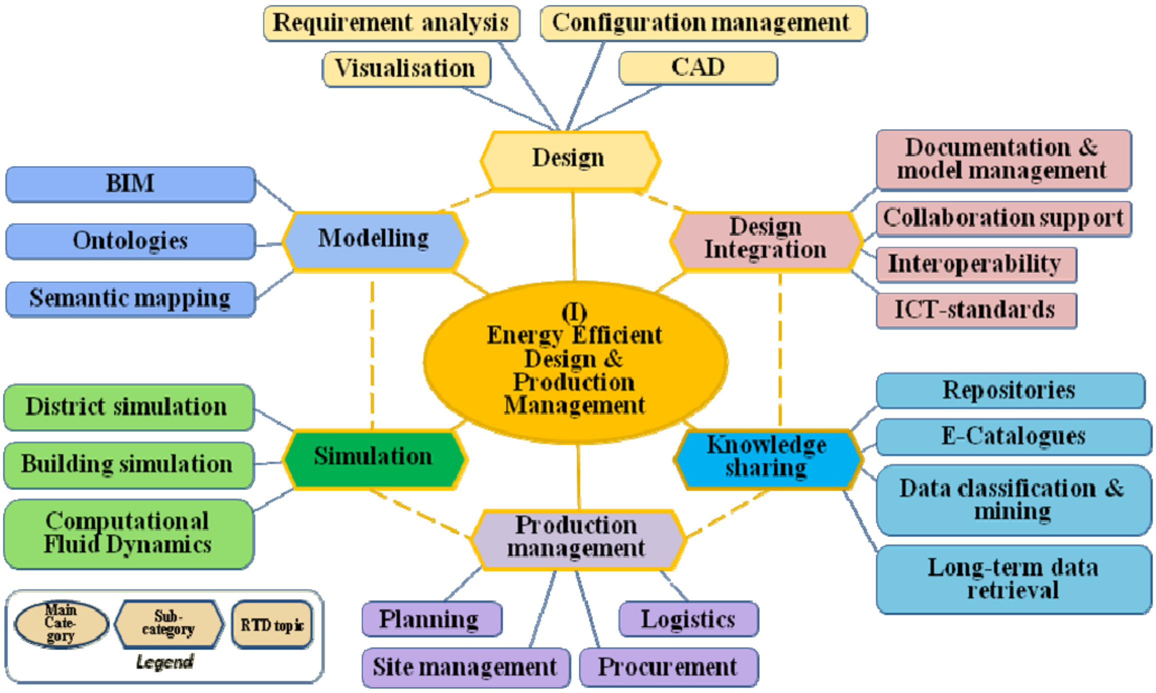

Figure 15: MCC (I) – Energy Efficient Design and Production Management

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

II. Intelligent and Integrated Control [MCC II]

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

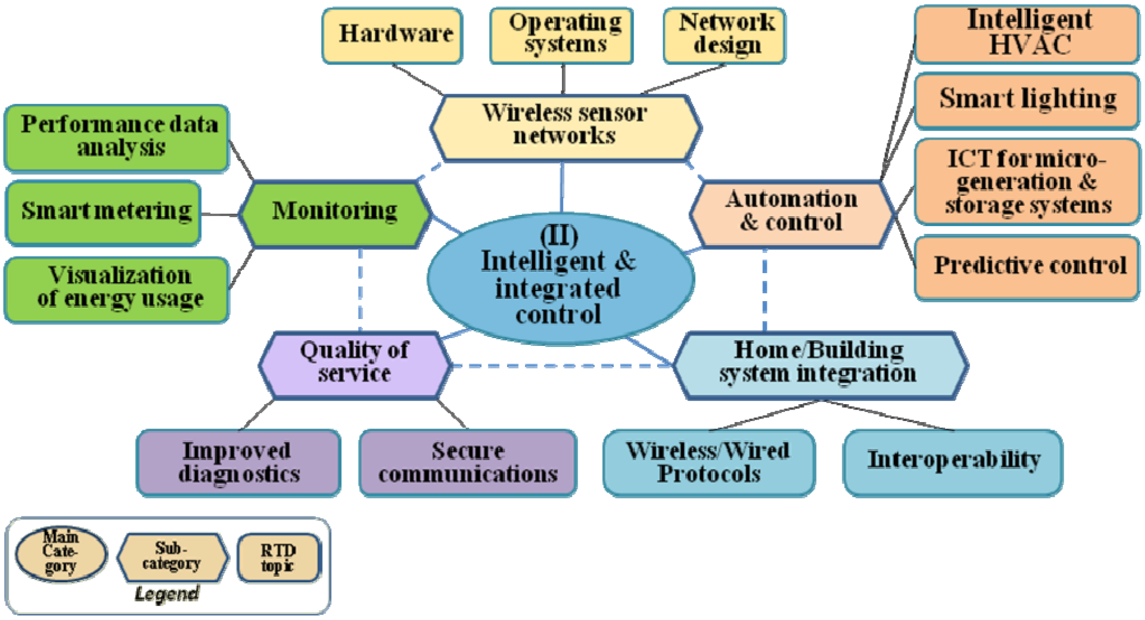

Figure 16: MCC (II) - Intelligent and Integrated Control

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

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

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

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

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

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

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

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

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

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

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

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

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

Improved diagnostics for efficient optimisation/improvement of

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

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

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

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

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

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

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

III. User Awareness and Decision Support [MCC III]

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

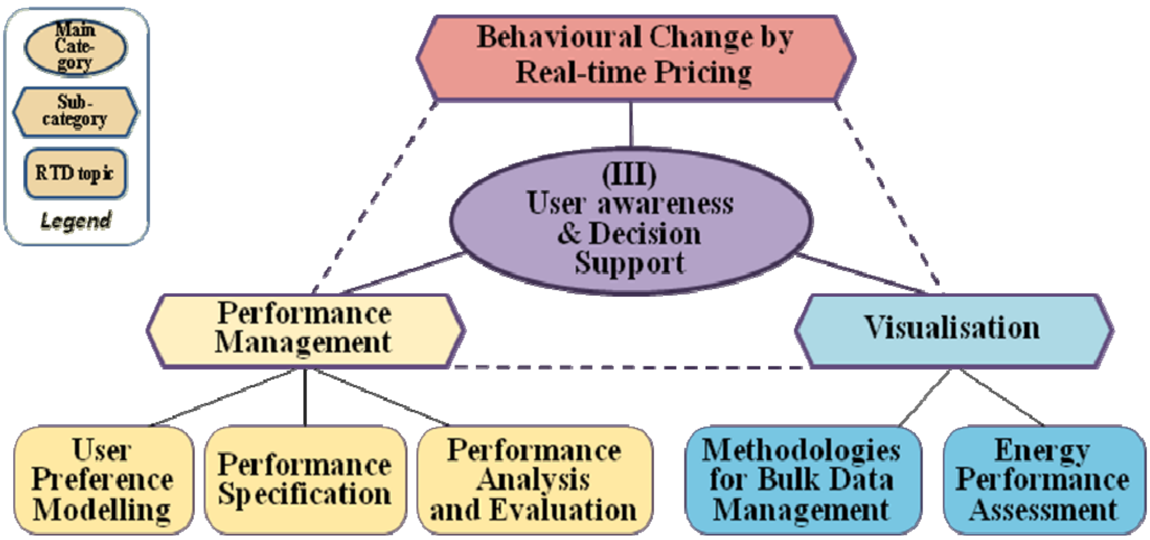

Figure 17: MCC (III) - User Awareness and Decision Support

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

Recent research in AI has focused on the (general) modelling of user preferences. However, there are a very limited number of systems for user preference modelling for HVAC and lighting systems available. In terms of performance specification there exist numerous national regulations. Furthermore, the number of tools supporting the evaluation of these performance specifications is limited. Knowledge and information exchange across national borders is limited. Last but not least many commercial Building Management Systems support trivial performance analysis functions. Complex, multi-criteria analysis functions are seldom available and need to be developed. Finally, it is important that Performance Specification tools can be easily integrated with design and decision support tools.

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

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

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

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

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

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

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

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

IV. Energy Management and Trading [MCC IV]

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

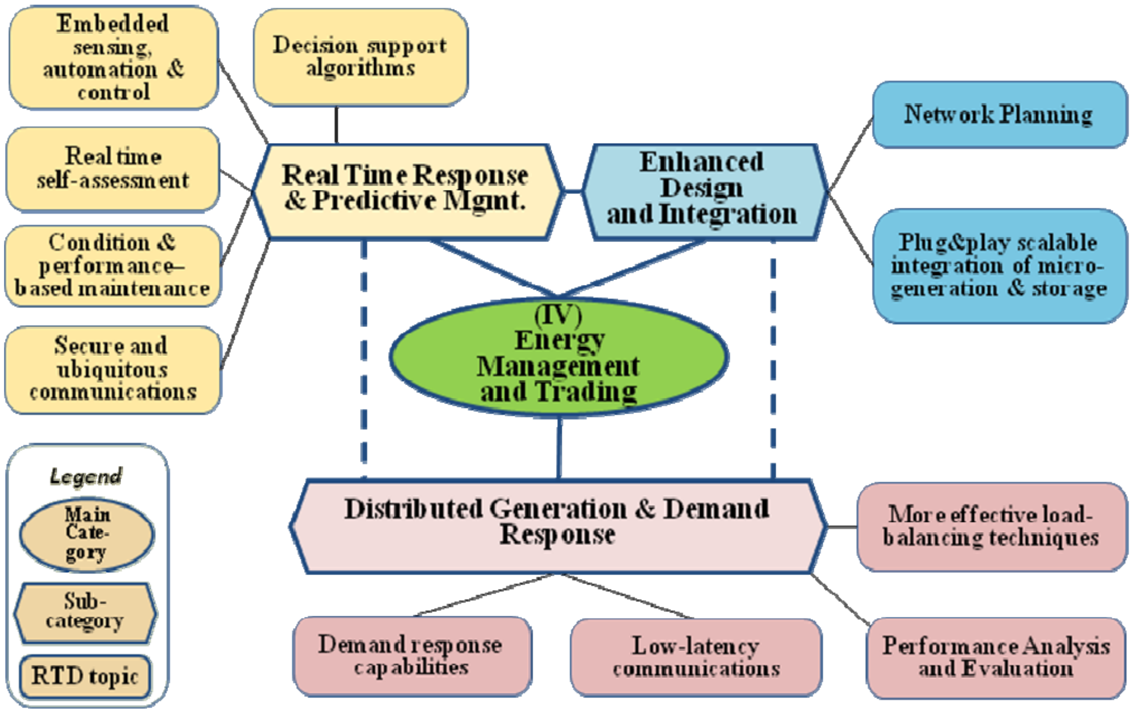

Figure 18: MCC (IV) - Energy Management and Trading

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

V. Integration Technologies [MCC V]

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

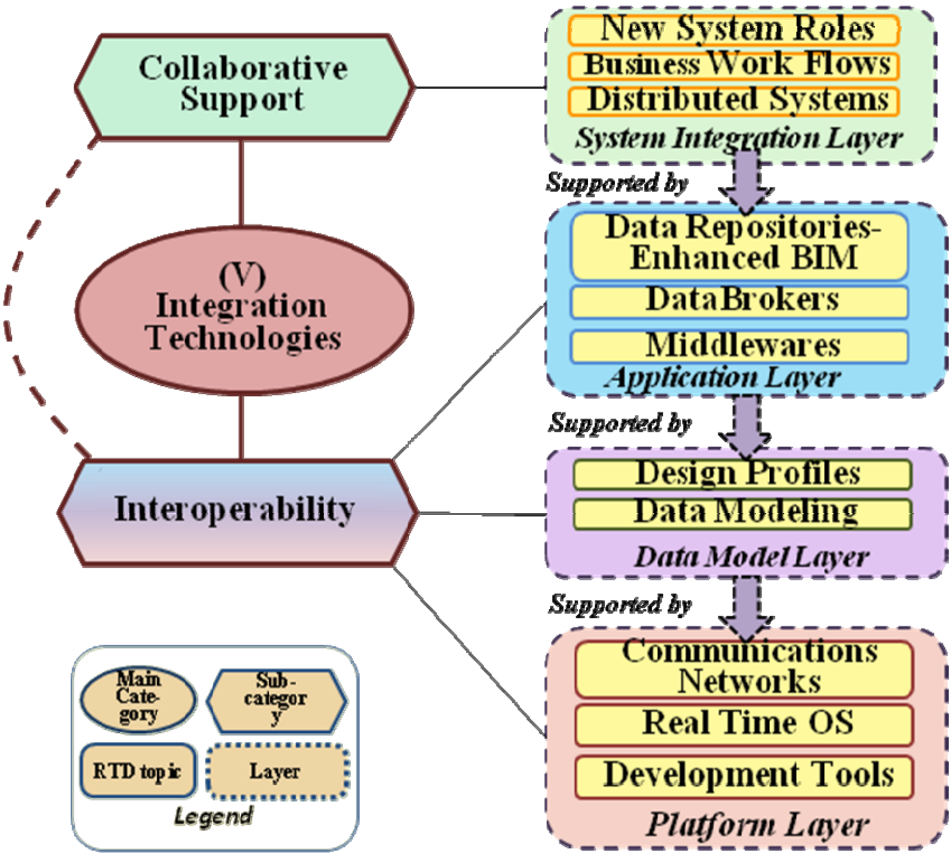

Figure 19: MCC (V) – Integration Technologies

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

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

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

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

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

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

Research Challenges

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

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

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

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

(MCC II) Intelligent and Integrated Control, including:

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

  (1) Wide band Programmable Logic Controller (PLC) interfaces;

  (2) New Virtual Private Network (VPN) embedded interfaces;

  (3) Low Power communication interfaces.
- Development Tools: As wireless components are penetrating the market, new development tools for wireless networks will be needed, such as Integrated Development Environments (IDEs) to allow easy, plug & play installation.
- It is also necessary to pay additional attention to improvement of building Sensing Infrastructures (SI) by development of seamless and dynamic end-to-end network compositions and service operations based on a wide range of components from sensor nodes, to Wi-Fi devices, RFID tags and readers. The development of a flexible wireless SI with

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

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

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

(MCC IV) Energy Management and Trading, including:

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

(MCC V) Integration Technologies, including:

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

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

Integration of RTD results

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

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

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

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

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

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

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

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

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

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

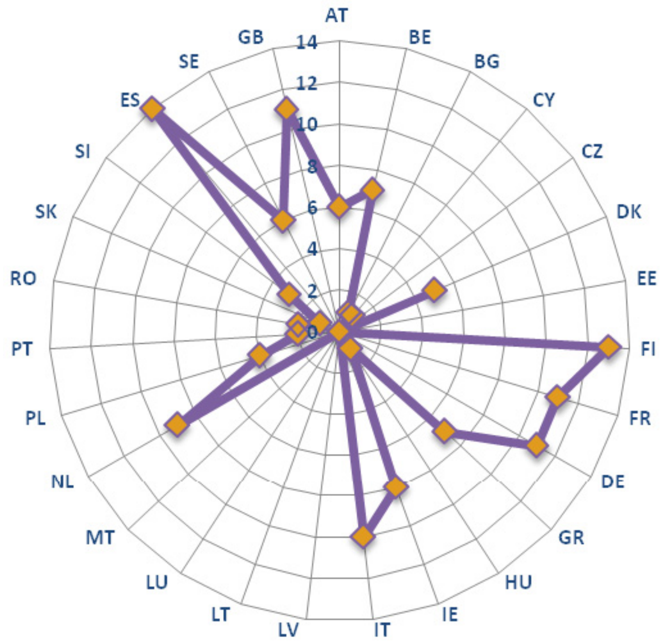

Figure 20: Distribution of selected RTD per country (Europe)

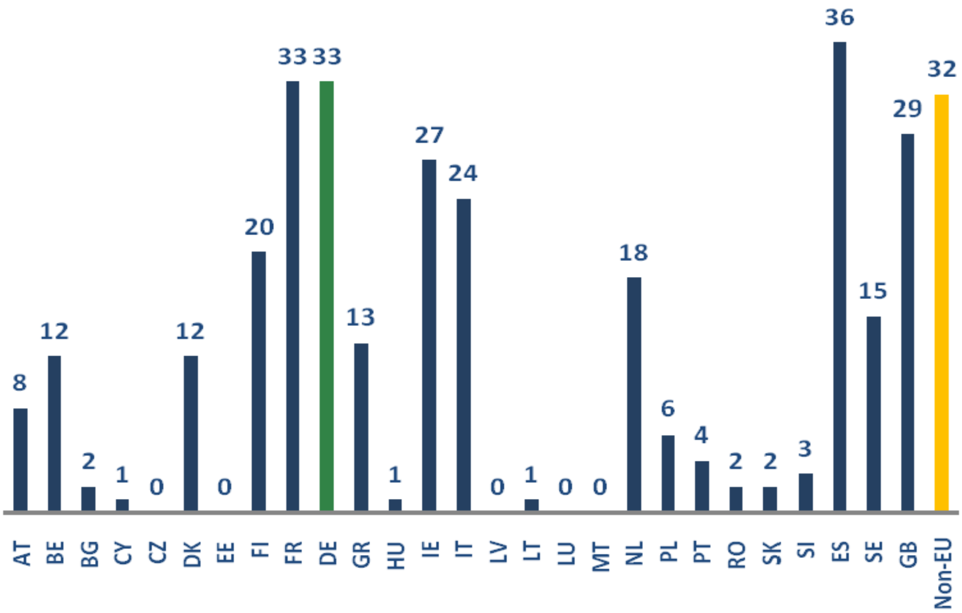

Figure 21: Number of all RTD participants per country

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

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

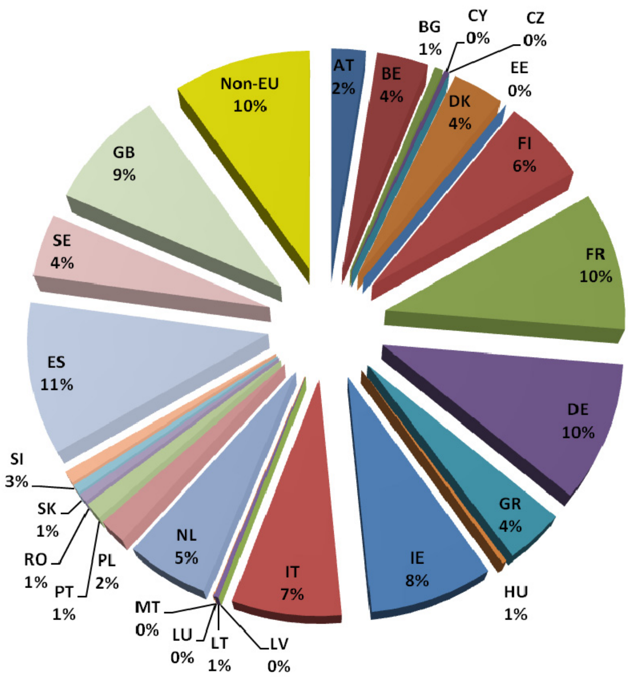

Figure 22: Percent distribution of all RTD participants per country

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

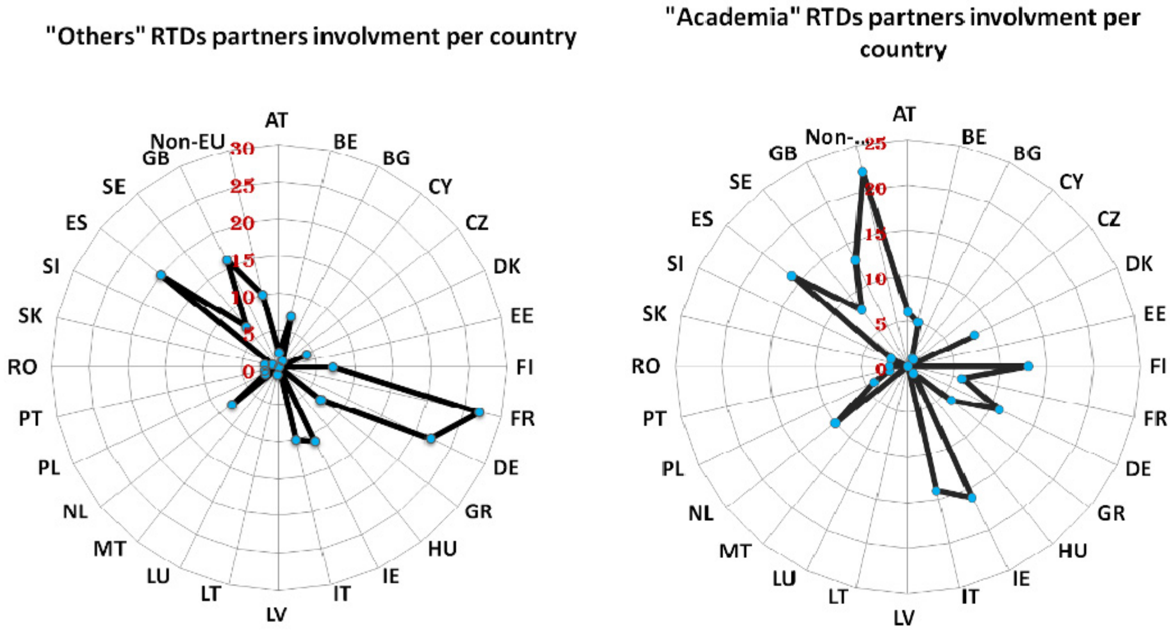

Figure 23: Distribution of RTD partners per country (non-EU included)

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

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

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