Gap Analysis of Current Best Practices in the Area of Continual Commissioning

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ABSTRACT: This paper analyses the status of Continual Commissioning (subsequently short-named as CC) aiming to improve the energy efficient design and operation of built artefacts. In order to develop a comprehensive vision of the CC market worldwide it is compulsory to establish a state-of-the-art analysis based on already existing Best Practices (BP). As a result of these identified challenges, commonalities, deficits, and potentials for collaboration are identified contributing to enhance harmonization between the CC-related technology developers. This paper proposes a systematic categorization approach to identify gaps in the current Best Practices in the area of Continual Commissioning. More than 500 companies and organizations related to this area have been analyzed, 100 of them have been selected for further categorization and analysis. The proposed method allows to identify major deficits of the related services offered within the specified categories. Finally, areas in CC which require substantial improvement are identified.

1 FRAMEWORK FOR ANALYSIS OF CC-RELATED SERVICES

1.1 *Selection and classification criteria*

A substantial part of the information about current Facility Management (subsequently named as FM) in general and the CC market in particular (i.e. companies offering this service) is open to the public. Many of these activities are managed in accordance with the norms for Open Source Modelling. (Guibault, Hugenholtz; 2006) However, CC-related companies and their services/activities vary in multiple characterization criteria, such as: size, time of service, participants, profile of the organization, composition, etc.

The selection and classification criteria, presented in this paper, will facilitate the categorization of CC activities by defining "virtual borders" between selected groups of specific services offered by their Providers. These are mostly industrial companies, but many of them are constantly involved in Research and Technology Development (subsequently named as R&D) activities for integrating their building energy systems at the data level, transforming those engineering systems into a business systems. It enables facilities executives to advance their businesses through an information-driven approach.

1.2 *Analysis framework*

In accordance with these factors we define the following steps as the analysis framework:

(1) Scanning of activities related to the domain of "Continual Commissioning in Buildings" from initial sources of information;

(2) Initial selection of CC-related companies by their activities; analysis of these activities in order to outline the Selection Criteria and its Domain. We propose a "bottom-up" approach in which strategy focuses on individual companies, businesses and places with less emphasis on sectors and/or current economic conditions;

(2.1) Introduction of terms and definitions, e.g. "Selection Criteria", "Classification", "Categories" etc.

(3) Analysis of selection results, including:

(3.1) Identification of the General Classification Parameters for selected Providers - used in the following Quantitative analysis;

(3.2) Evaluation of Providers' achievements, current and future aims, with the intention to:

(3.3) Outline the Initial Categorization Parameters, leading to:

(4) Development of the final Main Classification Categories (MCC) for "CC Providers' Activities" with verification against the domain of Selection Criteria. We propose a "bottom-up" approach again here, when the name and overview of each MCC

based on the individual attributes of those service Providers selected;
(4.1) Categorization and mapping of selected Providers, and
(5) Creation of a common structural "picture" for the Continual Commissioning market worldwide by applying a Quantitative analysis; performing a Qualitative analysis aiming to identify undeveloped areas/gaps within this market.

A graphical representation for the proposed steps of the analysis' framework is presented in Figure 1.

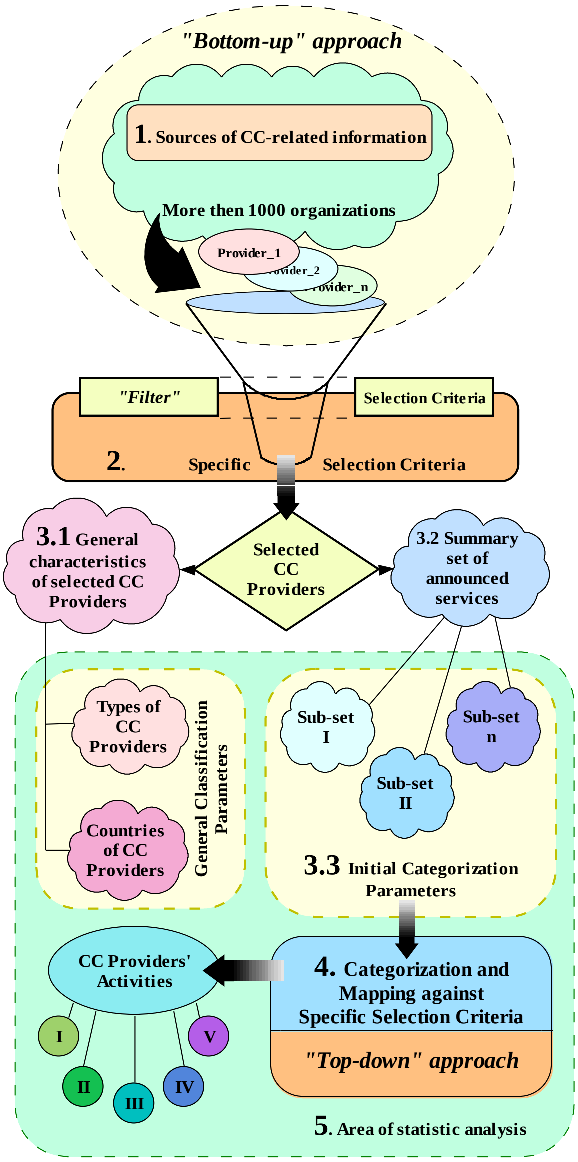

Figure 1. Methodology of CC-related best practices analysis.

The proposed methodology is based on a framework developed by the authors as a part of the REEB research project (REEB, EU FP7 R&D, 2010). In this method the products of Providers are described as a set of activities intended to be a service offered to customers of each selected Provider.

The expected results will lead to an improved understanding of the impact from CC as a service supporting Energy Efficiency in Buildings (subsequently named as EE).

2 INITIAL SOURCES OF INFORMATION

In order to form a generic approach for identifying and prioritizing a comprehensive set of specific service Providers, whose activities are associated with continual improvement of EE in buildings, we analyzed further sources of information:
(I) Open – source informational domains such as European research platforms, programs and initiatives, e.g. COST, EUREKA, EU General Framework, 2013, ECTP, CORDIS, Sustainable Energy Ireland, Commission for Energy Regulation, etc.
(II) The REEB, EU FP7 project Work Package 3 library, originally developed and based on information provided by the ManuBuild project, EU FP7 R&D, 2007.

Furthermore, general information about developers of modern technologies, technology platforms, national and international scientific programs and commercial organizations have been collected.

3 DOMAIN OF SELECTION CRITERIA

Further filtering became possible through application of the Initial Selection Criteria. An easy understandable consequence of this process is reflected in Figure 2.

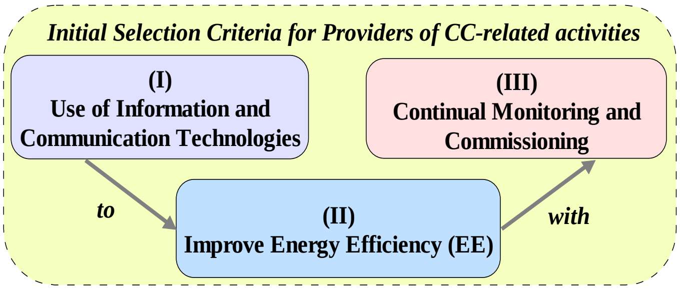

Figure 2. Selection Criteria for Providers of Continual Commissioning activities.

In order to explain the Initial Selection Criteria, we further subdivided into Domain Selection Criteria (DSC). Figure 3 represents the first part of DSC, i.e. Area (I), use of Information and Communication Technologies (ICT_:

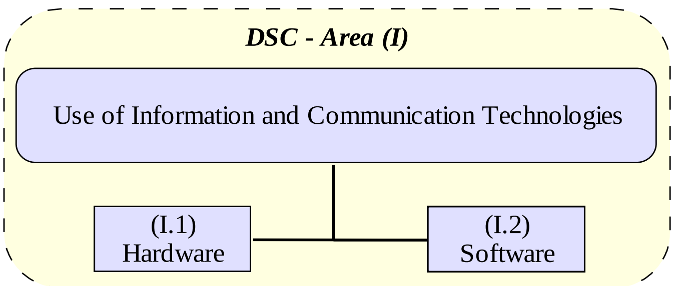

Figure 3. Domain of Selection Criteria - Area (I).

DSC Area (I): Deployment of Information and Communication Technologies, includes two sub-domains:

(I.1) Hardware deployment. This sub-domain specifies an exploitation of different types (e.g. wireless and wired) components such as: smart meters; wireless sensors, actuators, and controllers; mobile devices, or novel end-user devices (e.g. holographic screens).

(I.2) Software development/deployment. This sub-domain represents advanced software including specific network operating systems, design tools for buildings and networks, Building Information Models (BIMs), building simulation tools, construction support software, operational software for data management and analysis, building control and automation software, and software for energy-efficient facility management.

DSC Area (II): Control of Energy Efficiency and Energy-Management:

Challenges related to the improvement of Energy Efficiency (EE) within buildings, such as strategies for effective energy management with ICT support and the optimization of buildings' energy consumption and production are summarized in this DSC Area, see Figure 4. We propose to subdivide this area into Energy - related Lifecycle Phases and Business Models.

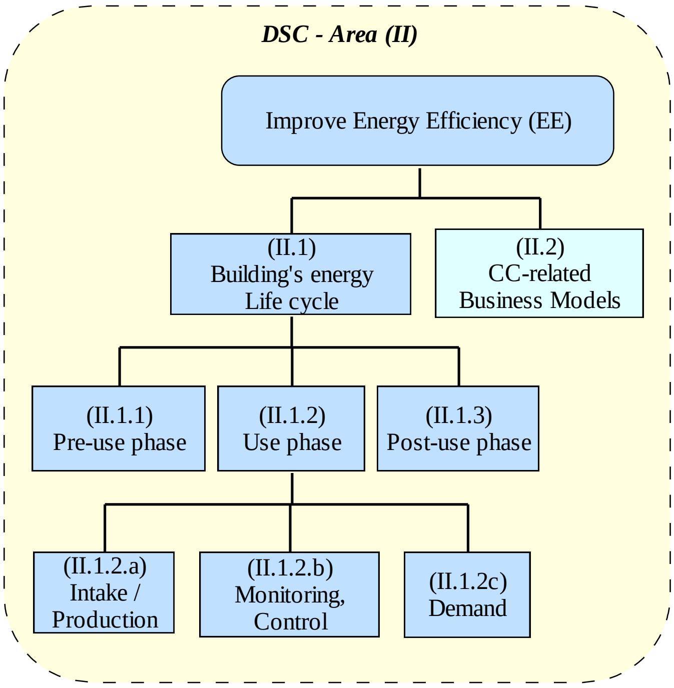

Figure 4. Domain Selection Criteria - Area (II).

(II.1) Energy - related Lifecycle Phases:

(II.1.1) Pre-use phase: This includes activities required for the production of a building and its components, which includes such activities as material extraction, production and transportation, and building construction itself;

(II.1.2) Use phase: Activities in this area are mostly determined by the management of the different Building Systems and Components (see III.3 below), and buildings in general. The Provider is supposed to deliver optimal user comfort for human activities in this phase.

(II.1.2.a) Energy Intake and Production. This includes activities in management of the energy intake from various sources (gas, electricity, renewables), i.e. maximization of the intake from renewable energy sources and minimization of CO_2 emissions from building operation;

(II.1.2.b) Monitoring and Control: This includes the optimized management of energy demand versus energy intake and energy generation from renewable sources (building as power-plant) by using efficient, real-time measurements and control algorithms;

(II.1.2.c) Energy Demand: This includes the control of energy demand through the availability of advanced monitoring tools for user comfort (temperature, humidity, CO2 level) and the control of the operational hours of other utilities in the building (e.g. computers, dryers, etc.).

(II.1.3) Post-use phase: This emphasizes the activities needed after the building's useful life, which includes the building's demolition and disposal, or possible reuse or recycling. We would suggest this phase is out of scope of this paper and will not be revised.

(II.2) Business Models:

Additionally, efficient energy management of buildings cannot be achieved without the development and implementation of innovative business models. In the future the provision of new, holistic and integrated Energy Services will be required. The emphasis is on the integrated delivery of energy provision from different sources (e.g. locally generated energy from solar panels combined with "back-up" from main grid). The market demand for these business models will determine the nature of the CC-industry in the future.

Area (III): Application of Continual Monitoring and Commissioning:

This area includes two important sub-domains, i.e. (III.1) Building Life-Cycle Phases, and (III.2) Building Services Systems and Components, see Figure 5.

(III.1) Life-Cycle Phases:

Firstly, the announced results of selected Providers should be analyzed with respect to their potential impact on the Life-Cycle Phases of buildings (i.e. development of innovative ICTs, as well as EE-directed business models). These phases include:

(III.1.a) EE Building Design: In the design phase the efficiency of installed systems can be substantially influenced and determined.

Especially, the Failure Mode & Effect Analysis (FMEA) for integration of existing systems and components needs to be done (for example the interaction of under-floor heating systems with so called "Intelligent Facade Systems").

(III.1.b) Construction: The complete and consistent handover of technical documentation and design materials after construction is essential for future efficient operation, inspection and maintenance of a facility. Currently, there is a deficit in flexible knowledge and document management systems as well as the efficient support of the (highly collaborative) commissioning processes.

(III.1.c) Retrofit / renovation of buildings: The development of cost-efficient, incremental, renovation strategies is essential to achieve a broad impact in the area of Continuous Commissioning in buildings. The availability of sophisticated tools for analysis and diagnostics of building' performance data is an essential requirement for this task.

(III.1.d) Maintenance, Inspection, and Operation: An integrated, advanced continual maintenance, inspection, planning and scheduling is another important requisite to ensure the long-term operation of buildings in an efficient way, avoiding the "gradually downgrading" of building performance over time.

(III.2) Building Systems and Components

The domain of services in the area of Building Systems and Components is important to overview, especially if these systems and components are embedded in complex monitoring and control systems. This includes:

(III.2.a) Heating, Ventilation and Air-Conditioning (HVAC) systems: which contribute to improved thermal comfort and quality for building occupants;

(III.2.b) Lighting system: which should use the latest technologies and materials along with proven optimal design to provide high levels of performance and reliability with minimal maintenance requirements for visual comfort of building occupants;

(III.2.c) Passive systems: this refers to energy-efficient technologies or design features used in buildings to maintain the optimal thermal comfort without power consumption.

(III.2.d) Renewable energy sources: this includes energy generation from such sources as water, wind, sun, geothermal, and biomass. Development of concepts or components addresses sustainable production and optimal control;

(III.2.e) Utility system's servicing activities: this addresses the provision of optimal building's functionality ensuring building' systems operate as efficiently as possible.

The development of this Domain is facilitating an easier selection and classification of samples from initial information. The selection process narrows the scope for the following analysis.

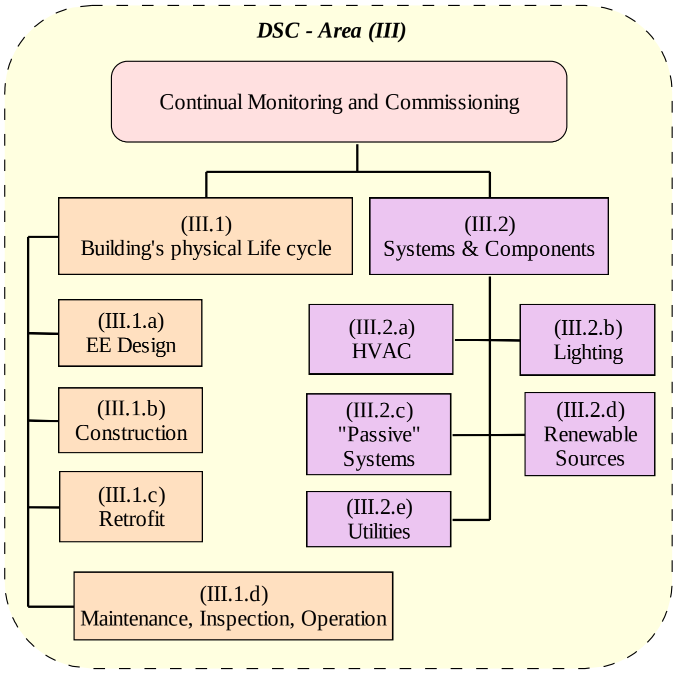

Figure 5. Domain of Selection Criteria - Area (III).

4 ANALYSIS OF SELECTION RESULTS

4.1 *Method for categorization*

The methods for categorizing a group of specific service Providers typically depends on a well specified set of attributes for each servicing area, which facilitates the classification of these Providers within specific categories.

We have decided to use a "Top-Down" approach for this categorization process. This method essentially breaks down a certain number of selected units into specific groups of so called "compositional categories". Each compositional category then could be refined in more detail on the following sub-category levels until the complete specification of each unit will satisfy the requirements on a logical basis. The aims of this task are:

- To select the most appropriate characteristics of each selected Provider;
- To find similar targets/final products, and
- To define these results as categories.

4.2 *Preliminary analysis tags*

The preliminary analysis was performed and the set of Initial Categorization Parameters was defined as a result of this analysis process, where areas of CC-related services considered, namely:

- Development of original concepts, methods and tools supporting optimal design, operation and management of built artefacts;
- Deployment of the modern ICT hardware/software and consultancy activities;
- Novel control and monitoring systems supporting the integration of global and local control strate-

gies applicable to industrial processes and living environment;
- Simulation and integration of products and services related to efficient energy supply, distribution, consumption and production within buildings;
- Activities related to the actual buildings' envelop construction, renovation and utilization.

4.3 *Results of preliminary analysis*

The development of these Initial Categorization Parameters, as mentioned above, is a result of a separate analysis and evaluation of information gained from the initial information sources. The overlapping issues and similarities were extracted during the analysis process.

As a consequence of the Provider's individuality, it is deemed difficult to group them under a single domain. However, it is possible to find similar/overlapping areas and outline these areas as specific classification categories. The number of these categories must be relatively small to not mislay the understanding of the global situation.

5 MAIN CLASSIFICATION CATEGORIES

The creation of category sets is done by mapping the Initial Categorization Parameters against the Domain Selection Criteria. These categories are further named as Main Classification Categories (MCC). Each of these MCC was broken down into four sub-categories to consequently develop a broad view on a various services offered by CC-related Providers, see Figure 6. Any specific areas of services, which is not falling into this structure, can be grouped into the "Other" sub-category within the related MCC.

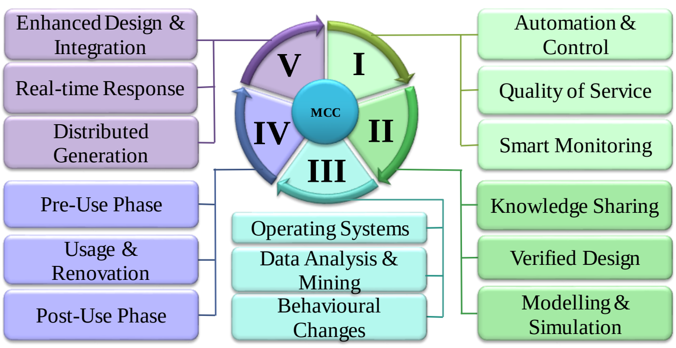

Figure 6. Continual Commissioning MCC I-V selection criteria.

The names and numbering for the five Main Classification Categories consolidated are the following:
(I) Intelligent FM (Facilities Management);
(II) Integrated Consultancy;
(III) Automated Commissioning;
(IV) Lifecycle Support;
(V) Energy Management & Trading.

6 RESULTS OF GAP ANALYSIS BASED ON MCC

A survey of over 1000 organizations worldwide, divided into five different geographical regions (i.e. named as "Ireland", "United Kingdom", "European Union", "Americas", "Asia/Oceania/Middle East"), was undertaken using qualitative and quantitative research techniques to obtain a better understanding of the Continual Commissioning – related services offered by these Providers. One hundred of them were selected and categorized by the MCC defined above. The consolidated results of the analysis of selected cases (named as Best Practices, BP) are reflected in Figure 7 which covers the available services defined by MCC in general.

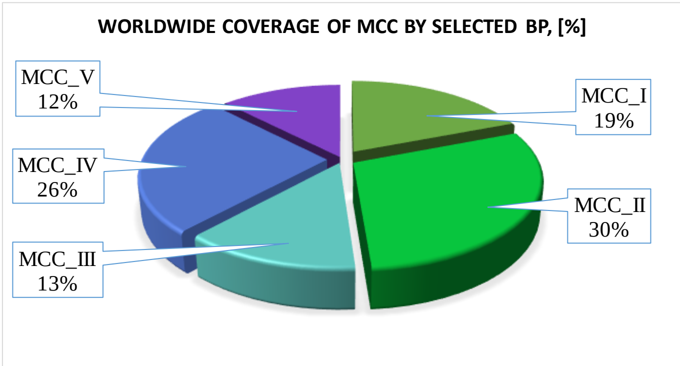

Figure 7. Worldwide coverage of MCC by selected BP.

A breakdown of CC-related services distributed by location parameter is reflected in Figure 8.

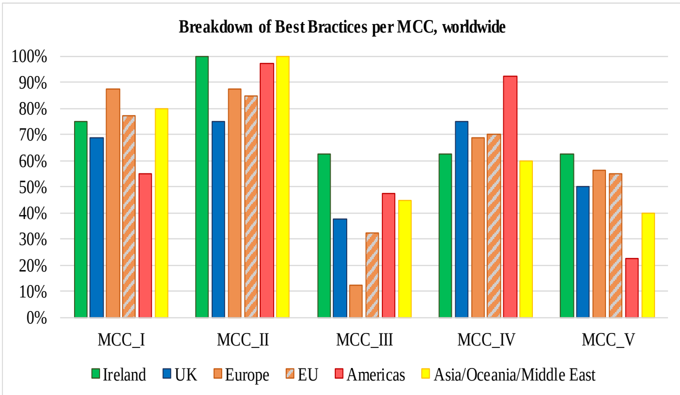

Figure 8. Breakdown of BP per MCC, worldwide.

More precise breakdown of BPs per MCC by location parameter is presented in Figure 9.

It becomes visible that the most uncovered category of services available is related to the Automated Commissioning area of Continual Commissioning, which consists of specific methods and strategies integration, as well as use of software tools and applications improving the overall EE. This refers to automate labor-intensive commissioning processes in order to continually analyze assets data and expose specific issues that need to be addressed in order to achieve optimal energy performance.

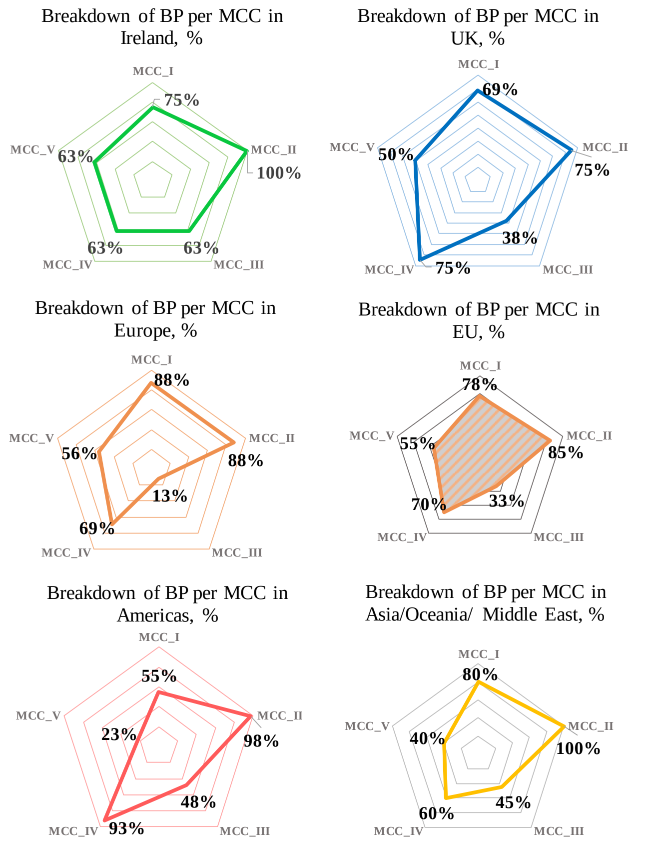

Figure 9. Precise breakdown of BPs per MCC by location parameter.

Figure 9 above clearly presents the distribution of selected BP cases per MCC by different region in the World. It is worthwhile to discuss the difference in presented results for Europe (i.e. Denmark, France, Italy, Germany, Holland and Spain) and the EU (i.e. same countries plus UK and Ireland) regions. It illustrates those modern tendencies in development and exploitation of CC-related theories, methodologies and approaches designed to satisfy the demand for Automated Commissioning techniques, especially in the UK and Ireland.

It is also possible to suggest only USA holds the leader positions on field of Continuous Commissioning services' market among Canada, Brazil, Chile, Argentina, Ecuador and Columbia, where Energy Management and Trading is an underdeveloped area.

Big progress in distribution of CC-related services admitted in Asia/Oceania/Middle East region (i.e. presented by India, Japan, China, Singapore, UAE, Australia and New Zealand), especially in Integrated Consultancy area.

7 CONCLUSIONS

The idea of using software tools with embedded intelligence that will automate labor-intensive commissioning processes in buildings has become important recently. This is reflected in many scientific and industrial attempts of developing systems which can continually monitor components and systems' performance in buildings. Operators and managers of buildings and energy systems have a demand in tools that can be used to address the lack of availability of consolidated performance data. Constant access to building performance information and operational measures will help to provide the necessary diagnosis and benchmarking abilities.

Instead of ad-hoc analysis of best practices prevalent today, a more systematic approach to this important aspect was developed. In this paper this systematic approach is of hierarchical nature.

Firstly, simple and robust filter criteria were defined to allow a clear selection of relevant actors.

Secondly, the initial categorization/grouping supported the identification of potential working collaborations and availed to enhance the harmonization between different R&D activities worldwide.

Our method is attempting to perform this task in an optimal manner. All results presented in this paper are based on open information sources such as web-sites with information presented in English, German, Chinese and Russian languages.

The authors do not claim that the analysis result is complete. Information about Providers presented in other languages, or those which exist as protected commercial information was not analyzed.

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