Deliverable 6.2
EeB Monitoring Methodology and Monitoring Report Year 2

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No & name	**D6.2 EeB Monitoring Methodology and Monitoring Report Year2**				
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DoW	This report provide a EeB programme monitoring methodology, applied to project cluster at the end of the second year of the project
Comments	This is the second release of this report. It includes the outcome of a cooperation with the 2 other CSAs - EEbers and SWIMing – which led to establishing a state of art of current practices, identification of challenges, future priorities and recommendations for each of the seven technology clusters identified in EeB-CA2.

Document change history			**EeB-CA2**
V	**Date**	**Author**	**Description**
1.	2016/11/15	Margherita Scotto as representative of D'Appolonia project team (DAPP)	ToC
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3	2017/01/13	Margherita Scotto as representative of D'Appolonia project team (DAPP)	Final version submitted
4	2017/03/15	Margherita Scotto as representative of D'Appolonia project team (DAPP)	Second version submitted – includes the outcome of the joint work with EEBERS and SWIMing CSAs.

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1 Executive Summary

The aim of this report is to present the monitoring results achieved thanks to the activities performed by the EEBCA2 project between M12 and M24.

The monitoring methodology and the analysis of data have been developed within two main phases:

- The first one delivered during the first year of the project results of the EeB PPP monitoring questionnaire circulated in April 2015;
- The second one – second year of the project - is reported in the current report and is based on the results collected with the second version of the questionnaire delivered in April 2016 and on line survey.

The driver for the assessment was extracted from the Energy Efficient buildings Multi-annual roadmap for the contractual PPP under Horizon 2020.

The roadmap identifies a value chain segmented in 6 main steps: Design, Technology building block, construction process, energy performance, end of life and cross cutting and integration.

In order to better represent the topics targeted during the assessment of the project a cauterization has been done considering seven technology-clusters, with different positions in the construction-related research and innovation value chain from the EeB Roadmap. These seven technology clusters have been identified and named as follows:

1. *Design,*
2. *Technology Building Blocks,*
3. *Advanced Materials & Nanotechnology,*
4. *Construction Process;*
5. *Energy Performance Monitoring and Management,*
6. *Novel Information and Communication Technologies ICT,*
7. *BIM, Data; Interoperability*.

During the first year:

The results from the questionnaire have been elaborated, double checked, and updated accordingly to further investigation in order to create a usable and reliable data base of EeB PPP project data accessible through the EeB-CA2 Knowledge Platform.

The first periodic reporting of FP7 project activities and results, taking into account scientific potential, technology readiness advancement for facilitating market uptake for innovative solutions developed in the context of EeB PPP projects is released to support third-parties initiatives or to EC itself in order to guarantee continuity of the monitoring process.

During the second year:

From a qualitative point of view the average value of the Technology Readiness Level (TRL) between the above seven clusters has been evaluated around 6,5, therefore a lot of technological improvements, economical investments as well as facilitating legislations are still necessary to support EeB PPP innovative solutions in entering the building market.

From the quantitative point of view, accordingly to work performed by project partner Steinbeis-Europa-Zentrum (SEZ) in the framework of task 5.1 "identification of exploitable technologies generated within EeB PPP projects" 226 of the targeted 267 exploitable results with a TRL of 6 or higher of 74 projects were clearly validated with a TRL of 6+.

This report aims to identify which are the target areas identified within the multi annual roadmap that have been respectively: well, partially and not adequately addressed by the 141different FP7 and H2020 running and closed projects assessed and funded under the EeB PPP.

For each WGs the most relevant target areas addressed could be summarized as follows:

WG Design: project supported in such framework aimed to develop design tools based on: model-based CAD approaches and interoperable interface; improved design accuracy applied with demo districts with the engagement of different stakeholders and on libraries of reference integrated within the tools themselves.

WG Technology Building Blocks. The projects supported in the framework of this WG best addressed the development and integration of: super insulating materials and components; improved technical properties for organic material; tools and methods to maximize user acceptance of adaptable envelopes; techniques to minimize Volitile Organic Compound (VOC, SVOC); envelopes improving natural light and ventilation in buildings and full scale demonstrations of adaptable envelope integration; smart building envelopes; innovative PV components; building and district level thermal storage; heating systems and storage at building and district levels; heat and power systems at building and district level; low GHG refrigerants; benchmarking and calculation tools; sensors and smart consumption displays for BEMS.

WG Construction Process, End of Life and Cross Cutting Information. The projects supported in the framework of this WG best addressed the development and integration of: standardize self-testing sensors/meters and energy performance verification procedures; full scale demonstration of deep building refurbishment based on mass customized envelopes.

WG Energy Performance Management and Monitoring. The projects supported in the framework of this WG best addressed the development of: monitoring tools for envelope and energy equipment performance; legal/societal/environmental performance indicators at EU level; self-diagnosis subsystems for conditional maintenance; virtual reality approaches to diagnosis; energy performance monitoring systems at district level; monitoring tools able to discriminate additional criteria from overall building energy performance; standard protocols for use-value measurements of energy efficiency in buildings.

WG BIM, Data and Interoperability The projects supported in the framework of this WG, focus on: developing enhanced BIM models and ontologies to describe interfaces of building and district projects; BIM tools able to merge building models and construction process management and relative control and certification methodologies; approaches to enforce long term legal and contractual validity of BIM.

WG ICT. The projects supported in the framework of ICT WG, as described in detail in EEBERS project, focus on identifying opportunities for synergies in ICT related RTD (Research in Technical Developments) in the EeB (energy efficient buildings) domain. The most relevant technological solutions assessed by EEBERS project have been identified and clustered within 5 main areas: Integration technologies; Energy management & trading; Tools for EE design & production management; Intelligent and integrated control (at building level); User awareness & decision support.

WG Advanced Materials and Nano Technologies. The projects supported in the framework of this WG best addressed the development of: super insulating materials and components; improved technical properties for organic materials; advanced low CO2 concrete; modular mass customized envelope solutions and full scale demonstrations of adaptable envelope integrations.

At the same time for each WGs the target areas that have not specifically addressed could be summarized as follows:

WG Design: this WG still need to address the definition of approaches to enforce the long term legal and contractual validity of building information models.

WG Technology Building Blocks: this WG still need to address some areas as: the easy use and cost efficiency of procedures to determine the structural load capacity of existing structures accurately; some material related aspects such as: the Development of chemical coupling agents and binders; Low-CO2 advanced concrete, materials for draining; Mass manufactured prefabricated modules, flexible lighting system using LEDs or OLEDs. Some demo and testing aspects related to: photo-catalyst or other de-polluting materials to extend the life of construction materials, demonstrations of adaptable envelope, modelling district energy consumption and building interactions systems and protocols to optimize energy storage and production at district level, new testing procedures to measure material performances, harmonize test procedures and efficiency labelling schemes. Some monitoring aspects such as: standardized functionalities for sensors and actuators, robust, resilient and reconfigurable sensor network: building embedded sensors; Interoperable smart meters.

WG Construction Process, End of Life and Cross Cutting Information. this WG still need to addressed some areas such as: techniques to measure the contribution of each critical component in energy efficient construction; the development of innovative construction processes to provide workers with safer and healthier environment and also systems to control in parallel works done by different experts; mobile factories composed by portable manufacturing facilities, placed near the construction site and tracking systems; waste collection, separation and reaction techniques in order to increase the reuse of the building waste into recycled composites and optimal re-usability or recyclability of different types of products; probabilistic tools to model/predict the ageing performance of zero energy building,: models and experimental tests capable of assessing the ageing properties of construction materials and components; comparison among member state in relation to energy labelling and its effect, develop an intelligent and well balanced portfolio of mechanisms to raise public awareness, set regulations, codes and practices, fiscal and financial tooling.

WG Energy Performance Management and Monitoring. With this WG the target areas that still need to be addressed is related to the enlargement of European network of use-value measurement laboratories.

The **WG BIM, Data and Interoperability a**nd **ICT** as described in the report this two WGs have been treated in a special way due to the fact that they are not directly included as segment of the roadmap. The area could be linked to the area BIM and ICT have been therefore all quite well or partially addressed.

WG Advanced Materials and Nano Technologies this WG still need to addressed some areas such as: the development of strategies to identify economic construction procedures for reuse of structures and procedures to determine the structural load capacity of existing structures accurately, which are easy to use and cost-efficient; technologies and methods to understand and maximise user acceptance, testing procedures to measure material performances, ICT components used to optimise the real time performance of envelopes, façade systems with movable sun barriers; basement insulation, mass manufactured prefabricated modules; the demonstration of photo-catalyst or other de-polluting, techniques to minimise the Volatile and Semi-volatile Organic Compound semi permeable insulation membranes and pigment.

After the final project review held in Brussels on January 27th 2017 in collaboration with the other two CSAs - EEbers and SWIMing – further development have been done to detail for each EeB-CA2 cluster:

- State of the art and current practice
- Challenges
- Future priorities and recommendations

- Impact

The information has been elaborated based on the outcomes of the technology assessments conducted in WP5, of the monitoring activities (WP6) and of the gap analysis.

This work has involved selected experts from ECTP members as detailed in each cluster. This work is presented in Section 10 of this report.

2 GAP analysis

In order to obtain a clear image of the general challenges and specific targets that have been addressed within the framework of Energy Efficiency Buildings by EU founded projects (FP7/H2020), so to establish the capacity of the past/ongoing funded projects to address the targets, we have created a methodology to carry out a gap analysis.

The EeB-CA2 Gap Analysis methodology foresees different phases of data collection and analysis, starting from elaborations already done with the project and delivered within two specific reports (6.1 and 5.2) and from the ECTP Monitoring sheet 2016.

To start off it was necessary to transform and or associate the 6 original Segments of the value chain defined within EeB Road Map into/to 7 Technology Clusters/Working Groups within EeB-CA2 project framework.

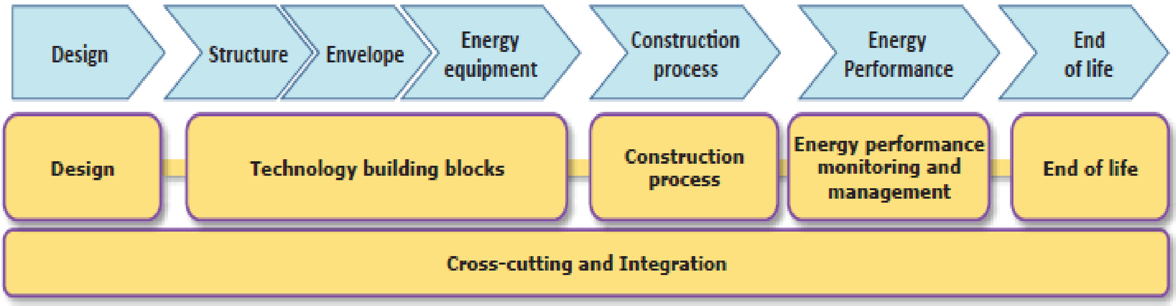


Figure 1: Representation of the segmentation of the value chain in the EeB Roadmap

The table below shows the 7 WGs identified and their relations with the segment of the roadmap. Some WGs considered strategic by both private and public stakeholders taking into account a comprehensive vision from industry along the value chain, including designers and architects, SMEs and service providers have been included and as report below are partially covered by one or more segments of the EEB roadmap.

EeB-PPP Technology Clusters/Working Groups	**EEB Road Map Segments of the Value Chain**
Design	Design
Technology Building Blocks	Technology Building Blocks (structure, envelope, energy equipment)
Advanced materials and nanotechnology	Partially covered within the Technology Building Blocks segment
Construction Process, End of Life and Cross Cutting information	Construction Process + End of life + Cross cutting and integration
Energy Performance Monitoring and Management	Energy Performance Monitoring and Management
BIM, Data, and Interoperability	Partially covered within the design and construction process segments
ICT	Covered by all the segments

Table 1 the relation between the 7 EeB-CA2 WGs and the roadmap segments

The second phase of the data collection was focused on re-mapping the original challenges, targets and targeted areas for the segments of the EEB Road Map with respect to the EeB-CA2 Working Group.

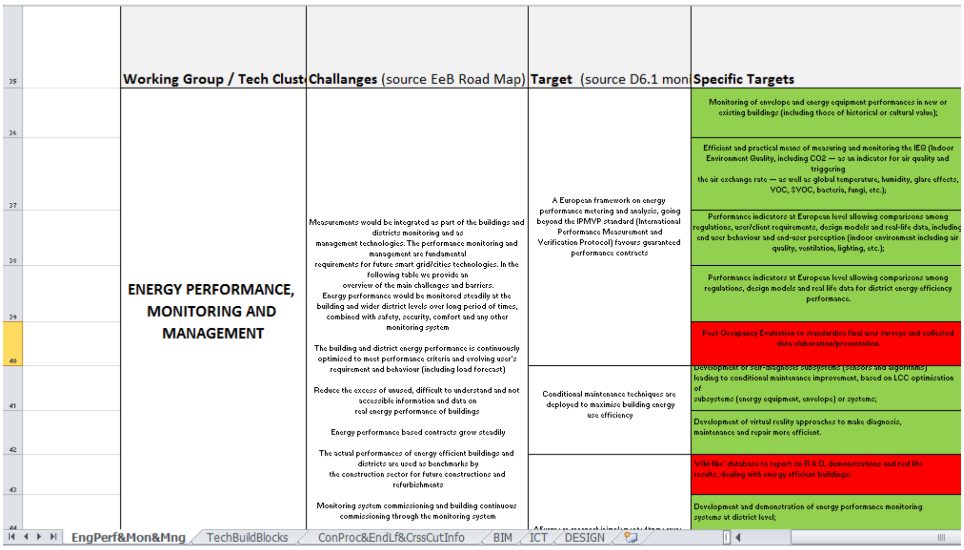


Figure 2: EeB-CA2 WGs - Challenges, targets and targeted areas of EEB roadmap

Then we analyzed the capacity of the past/ongoing funded projects to address the targeted areas by identifying and classifying:

- All validated projects' results with Technology Readiness Level +6, of both FP7/H2020 projects.
- All running FP7 and H2020 projects that have produced results not yet validated or that is in an early phase but is dealing with the specific target area and could be producer of relevant, promising or highly promising results in the future.

To facilitate this procedure we created an excel sheet for each Working Group, containing all related FP7 and H2020 projects, and classified all related (TRL+6) project results under three main areas: Highly Promising / Promising / Relevant, starting from EeB-CA2 project Deliverable 5.2.

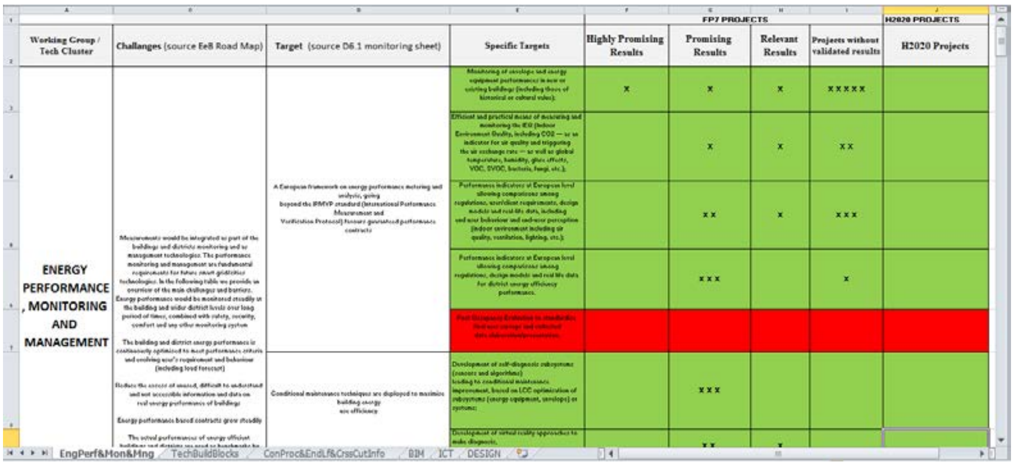


Figure 3: EeB-CA2 WGs - Challenges, targets and targeted areas of EEB roadmap

Finally, having created all the necessary support documents we continued with the Gap Analysis by establishing a ranking system with three level of "relevance" so to analyze and classify the capacity of each past/ongoing funded project to address EEB Roadmap targeted areas.

In this scenario we defined the following criteria for the ranking levels:

- Targets that have been quite well addressed – for which its possible to find highly promising and promising project results based on the activites performed within the assessment of technologies (D5.2). For such targets its also possible that currently running FP7 and H2020 projects are addressing such topics but have not yet identified specific and validated results
- Targets partially addressed –for which its possible to find relevant project results based on the analysis performed within the technologies' assessment (D5.2). For such targets its also possible that currently running FP7 and H2020 projects are addressing such topics but have not identified specific results yet
- Targets not specifically addressed - no clear match with running FP7 and H2020 projects

In the following sections we report a brief introduction, WG per WG, on the importance of the working group and their currently achieved results.

In the "highly promising", "promising" and "relevant results" columns each "X" corresponds to a validated result while in the columns "FP7 Projects without validated results" and "H2020 Projects" each "X" correspond to an ongoing project. From the number of records on each cell it is qualitative clear which are the areas with the higher efforts spent in terms of research actions.

All projects assessed within this gap analysis have been originally assigned to two different Technology Clusters and related Working Groups. This gap analysis of the addressed target areas considers only each project's "first Technology Cluster", therefore excluding the assesement of each projects' capacity to address other target areas related to the 2° Technology Cluster of origin. At the end of each WG's dedicated section we have included a list of the all the 2° Technology Cluster/Working group related to the projects with the aim of facilitating further analysis of the addressed target areas in a second phase.

3 Design

3.1 Analysis of the scenario

Good quality design is an integral part of sustainable development. Achieving good design is about creating places, buildings, or spaces that work well for everyone, look good, last well, and will adapt to the needs of future generations.

Good design responds in a practical and creative way to both the function and identity of a place. It puts land, water, drainage, energy, community, economic, infrastructure and other such resources to the best possible use – over the long as well as the short term.

Given the rapid development of emerging construction opportunities, owners should demand faster projects, lower costs and better buildings.

Architectural models have changed. Instead of 2D drawings, 3D computer designs using Building Information Modeling (BIM) are becoming the standard, providing owners better visualization.

More and more design firms are adopting 5D models at the earliest stages of design. These models show owners how early design concepts affect cost, schedule and constructability, allowing them to evaluate large-scale options and make informed decisions.

Design and construction firms are increasingly bringing energy-efficiency analysis into the early design and construction process.

In such context the Challenge identified at EU level foreseen that the design of energy/ resource efficient buildings (new or to be refurbished) must involve all stake-holders within a collaborative approach, allowing cost-efficient solutions Improving the planning process implies shared data, practices and tools with proper training and education.

In the framework of EeB-CA2 project it has been analysed that 73 innovations have been developed in the segment of the Design technology cluster. According to the data collected from the survey launched 66 of 73 innovations were rated with a specific TRL. The relevant or better promising results (validated TRL of 6-9) are of about the 71% of the rated innovations, where the 3% (i.e. 2 solutions) corresponds to the solution ready to be exploited.

3.2 Target Areas Gap analysis

3.2.1 Target Areas quite well addressed

Based on the analysis performed in the D5.2 no one of the identified results have been labelled as highly promising but there are primising results and the target areas considered quite well addressed are 3 as detailed below.

	FP7 PROJECTS				**H2020 Projects**
Targeted Areas	**Highly Promising**	**Promising results**	**Relevant results**	**Projects without validated results**	**H2020 Projects**
TA1.1		**xx**		**xx**	
TA2.2		**xx**		**xxxxx**	**x**
TA2.3		**xx**		**x**	

Table 2 : WG design- Target Areas well addressed

In which:

1. TA1.1: Eco-design tools for new buildings involving **model-based CAD approaches and interoperable interface**;
2. TA2.2: Innovative design tools for refurbishment (from building to district, including those having an historical and cultural value) with **improved design accuracy** validated on large scale district refurbishment **demonstration and involving all stakeholders**;
3. TA2.3: **Libraries of reference** design solutions (including EE product catalogue, good practices, compliance with building codes) with semantic research tools.

3.2.2 Target Areas partially addressed

The Target Areas considered partially addressed are 7 as detailed below.

	FP7 PROJECTS		**H2020 Projects**
Targeted Areas	**Relevant results**	**Projects without validated results**	**H2020 Projects**
TA1.2		**xxxx**	
TA1.3		**xx**	
TA2.1		**x**	
TA3.1		**xx**	
TA3.2		**xx**	
TA3.3:		**xx**	
TA3.4		**x**	

Table 3 : WG design- Target Areas partially addressed

In which:

1. TA1.2: Innovative **training approaches** to promote design tools for refurbishment;
2. TA1.3: **Eco design and resource efficient approaches** are implemented **for** all new technology development **projects using LCA and European data bases allowing responsible sourcing;**
3. TA2.1: **Shared engineering and economic databases** (materials, products, reference design solutions, building energy profiles, user group profiles) to support the minimisation of building GHG emissions and their cost of ownership (new and refurbished buildings, including buildings of historical and cultural value);
4. TA3.1: **Enhanced BIM models** based on standardised energy efficient attributes and modelling of building energy profiles;
5. TA3.2: **Ontologies (data models)** to describe materials, equipment and technology interfaces typical **of building and district projects**;
6. TA3.3: Cost effective **BIM tools** able to merge building models and building construction process management;
7. TA3.4: **BIM control and certification methodologies**.

3.2.3 Target Areas not specifically addressed

From the analysis performed only one target area seems not specifically addressed: TA3.5: Approaches to **enforce the long term legal and contractual validity of building information models.**

3.2.4 Other issues

It addition to the 13 projects that have been included in the technology building block WG there are 2 projects that have identified design as their second cluster as reported below.

Projects included in Design as 2° Technology Clusters	1° Technology Cluster
MEEFS Retrofitting	Technology Building Blocks
BuildHEAT	

Table 4 : WG Design projects as 2° Technology Clusters

It has to be reported in addition that the target areas TA3.1 - TA3.2 - TA3.3 - TA3.4 - TA3.5, have been also addressed by the BIM WG so in the section 7 are included further analysis of the achievements in the specific target areas.

4 Technology Building Blocks

4.1 Analysis of the scenario

High Level Expert Group's 2015 Final Report on Key Enabling Technologies (HLG-KET) confirms, with EU Commission support, that Key Enabling Technology development and use represents great potential to drive innovation and stimulate Europe's competitiveness and manufacturing renaissance.

Key Enabling Technologies such as: advanced manufacturing technologies, advanced materials, industrial biotechnologies, micro and Nano-electronics, nanotechnologies and photonics, are indispensable Technology Building Blocks capable of unlocking innovation, providing added value and underpinning a wide range of product applications in strategic European value chains. For these reasons KETs largely influence economic conditions and employment, in other words the quality of life of European citizens. Furthermore KETs contribute largely to drive Europe's competitive advantages in various products / services and multiple domains such as: automotive, aeronautics, engineering, space, chemicals, textiles, building and infrastructures, agriculture and healthcare. The application of KETs can further revolutionize processes; modernize manufacturing, reducing production costs and our reliance on finite materials, energy consumption, waste and pollution.

Facts & Figures:

European manufacturing is losing competitiveness do to both rapidly changing geopolitical and economic scenario and the need to develop new up to date strategies. The global KET market estimated value is 1 trillion euros.

The European Union is aligning different policy and strategy instruments in order to support industrial deployment of KETs (New European Industrial Policy-Horizon 2020-EU structural and investment funds and EU Investment Bank). Horizon 2020 first work program 2014-2015 called for more than 20 KETs pilot lines in the areas of high industrial interest and innovation potential in order to move towards closer-to-market projects. Cross-fertilization between KETs and the inclusion of market. Oriented selection criteria have been established in order to increase industry participation along the value chain: business and exploitation plans, commitment to first manufacturing in Europe, introduction of Technology Readiness Levels in research topics.

EEB PPP funded projects' contribution to EU's strategy towards global Technology building blocks leadership

Aerogel based on the high silica content precursor to be adopted for insulation purposes, simulation models for boiling on nanostructured surfaces and heat exchange, lower energy consumption in day-to day operation and inside lighting, adjustable formwork for the production of the above modular panels with variable dimensions are only few of the 180 innovations developed in the segment of the Technology Building Blocks technology cluster.

This segment was indicated as the main relevant for 40 projects that led to the definition, implementation and testing of 180 innovations, where only 149 were rated with a specific TRL. Half of these innovations were rated as promising results (i.e.

52%), with 41 innovations having TRL 6, 28 with TRL 7, 3 with TRL 8 and 5 are the solutions ready to be exploited as showed in Figure 6. The most active projects in Technology Building Blocks technology cluster are BEEMUP, EnRiMa, and HIPIN sorted out descending for TRL.

Furthermore, this segment was indicated as secondary relevant group for 3 projects that led to the definition, implementation and testing of 4 innovations having a relevant average TRL 8.

4.2 Target Areas Gap analysis

Starting from the work done within the Multi annual roadmap the Target Areas that could be directly associate to the Technology Building Block are 54. Such target areas have been matched with the EeB ppp projects and an assessment was performed ranking the addressed target areas within three main groups as above explained. Of the 54 target areas identified, 27 (related to structure and envelope) have been assessed also in the framework of Advance materials and nanotecgnologies WG as reported in section 9.

4.2.1 Target Areas quite well addressed

The Target Areas considered quite well addressed are 17 as detailed below.

Targeted Areas	FP7 Projects				H2020 Projects
	Highly Promising	**Promising results**	**Relevant results**	**Projects without validated results**	**H2020 Projects from abstract**
TA6.1	xxx	x		xxxxxxx	xxxx
TA6.3		x		xx	x
TA7.1	xxx	x			x
TA7.2		x		xx	
TA8.1		x			xx
TA8.7		x		x	x
TA9.1	x		x	x	x
TA9.2	x				x
TA10.2	x				xx
TA10.3		x			
TA10.5	x				
TA10.11	x				
TA11.2	x	x	x	x	
TA12.1	x				xx
TA12.5	x				xxxx
TA12.9		x			
TA13.1		x		x	

Table 5 : WG Technology Building Block- Target Areas well addressed

In which:

1. TA6.1: Development of innovative **super insulating materials and components,** and associated manufacturing processes, for refurbishing existing buildings (including those of historical and cultural value) and new buildings;
2. TA6.3: **Improve technical properties** (e.g. fire resistance) for organic materials;
3. TA7.1: Technologies and methods to understand and maximize **user acceptance** of adaptable envelopes in new and existing buildings (including buildings of historical and cultural value), addressing for instance air quality, moisture control, ventilation control or automated blinds, with interrelated issues of summer overheating, airtightness and indoor air quality;
4. TA7.2: Techniques to **minimize the Volatile and Semi-volatile Organic Compound (VOC, SVOC)** content of building materials (in the production phase and the use-phase);
5. TA8.1: Development and manufacturing of envelope improving and **optimizing natural light and ventilation** inside building;
6. TA8.7: Full **scale demonstrations** of adaptable envelope integration in building refurbishment projects, including smart insulation materials (e.g. aerogels, vacuum insulation panels or other innovative materials);
7. TA9.1: **Smart building envelopes** capable of adapting their energy generation and storage to external condition;
8. TA9.2: Integration of existing and innovative **PV components** (e.g. OPV, DSSC) into building envelopes;
9. TA10.2: Building integrated **thermal storage** (at building and district level);
10. TA10.3: Space and domestic hot water **heating systems integrated** at building and district level (including for instance Hybrid heat pumps or Thermo-electrical heat pumps) combined with storage;
11. TA10.5: **Combined Heat and Power systems integrated** at building and district levels, fully exploiting the renewable energy potential;
12. TA10.11: **Low GHG refrigerants**;
13. TA11.2: **Benchmarking and calculation tools** to deliver information to decision makers (architects, engineers, professional builders) on energy performance of different technologies;
14. TA12.1:Multi-parameter (light, temperature, air quality, moisture, instrumentation of HVAC) low cost **sensors for BEMS** integration;
15. TA12.5: Interoperable and adaptable **BEMS** able to optimize energy use spatially (at a building and district level) and temporally with predicting capability (energy loads forecast);
16. TA12.9: **Smart consumption display** to motivate users at reducing their energy needs through behavioral changes and/or good practices implementation;
17. TA13.1: Development and demonstration of **multi-scale real time optimization tools** (flat, building, district, city-wide level) including peak load management, demand-side management, building- and grid-integrated thermal and electrical energy storage, having the potential for energy storage pooling and local energy generation (based on reliable data model for neighborhood/district level energy systems).

4.2.2 Target Areas partially addressed

The Target Areas considered partially addressed are 17 as detailed below.

Targeted Areas	FP7 Projects		H2020 Projects
	Relevant results	**Projects without validated results**	**H2020 Projects from abstract**
TA4.1			**xx**
TA5.1		**xxxx**	**x**
TA6.2	**x**	**x**	**x**
TA6.5		**xxxx**	**xx**
TA6.10			**xx**
TA8.2		**x**	**xx**
TA8.3			**x**
TA9.3		**x**	
TA9.4		**x**	
TA10.1			**x**
TA10.4			**x**
TA10.7	**x**	**x**	**x**
TA10.8		**x**	**x**
TA10.9		**x**	**x**
TA10.10			**x**
TA11.1			**xx**
TA13.2			**x**

Table 6 : WG Technology Building Block- Target Areas partially addressed

In which:

1. TA4.1: Development of **strategies** to identify economic construction procedures for **reuse of structures**;
2. TA5.1: **Development** of novel cost competitive high volume and high performance **eco-construction materials** (including cement, concrete, gypsum, glass, steel, FRP materials, wood, to name a few) to cost efficiently cut down CO2 emissions of the construction sector and associated with low embodied carbon and improved resource efficiency;
3. TA6.2: New **value chains for bio-based construction materials** and bio-based treatments considering the complete life cycle;
4. TA6.5: New masonry based **building components with integrated** high-efficient **insulation materials**;
5. TA6.10: **Modular**, 'plug and play', **mass customized envelope solutions** to ease construction processes and replacement of components (i.e. windows);
6. TA8.2: Development and manufacturing of **energy storing converting materials** (e.g., Phase Change Materials and switchable glazing (e.g. thermochromic, photochromic or electrochromic) combined with **PV in glazing**

panes);

7. TA8.3: Development of semi permeable **insulation membranes and pigments** with adaptable absorption reflection spectrum, Façade component with changing IR absorption and reflection on demand in combination with insulation and switchable U-values;
8. TA9.3: **System integration of 'thermally activated' material** to reduce energy consumption;
9. TA9.4: **Interaction with smart grid/city systems**;
10. TA10.1: Building **integrated electrical storage** (building and district level);
11. TA10.4: **Cooling systems integrated** at building level and district level (including Heat pumps and storage);
12. TA10.7: **Renewable energy production** (heating, cooling, electricity) integrated at building level;
13. TA10.8: **Renewable energy production** (heating, cooling, and electricity) integrated at **district level** (incl. heat networks);
14. TA10.9: **Building integrated Ventilation systems** with heat recovery (air quality, air tightness);
15. TA10.10: **Heat management and optimization** (high/low temperature systems) at **district level** (e.g. exploiting ICT or waste heat recovery technologies — e.g. Organic Rankine Cycles — from industrial facilities);
16. TA11.1: Development of **novel methodologies** to set up more stringent and **ambitious standards** with a continuous improvement approach **for different regions/climate conditions** across Europe;
17. TA13.2: **Holistic control strategies** based on building simulation tools.

4.2.3 Target Areas not specifically addressed

The Target Areas considered not specifically addressed are 20 as detailed below.

1. TA4.2: Development of **procedures to determine the structural load capacity** of existing structures accurately, which are easy to use and cost-efficient;
2. TA6.4: Development of **chemical coupling agents and binders;**
3. TA6.6: **Low-CO2 advanced concrete** available for durable building envelopes;
4. TA6.7: Basement **insulation, moisture protecting systems** and new building **materials for draining**;
5. TA6.8: **Mass manufactured prefabricated modules** for optimum cost, performance, product handling and personal safety during construction, both for new buildings and for refurbishing;
6. TA6.9: **Demonstration of photo-catalyst or other de-polluting materials to extend the life of construction materials** (with e.g. automatic cleaning process) and at the same time substantially decrease the concentration of some air pollutants in urban air (COV, SOx, NOx), especially in confined spaces such as canyon streets, tunnels and parking,
7. TA8.4: New **testing procedures to measure material performances** (e.g. with reference also to adaptive performances), including a wide range of expected exposure conditions;
8. TA8.8: **Full scale demonstrations of adaptable envelope** integration in **district** refurbishment project;

9. TA10.6: **Flexible and active demand** to optimize local production/consumption strategies;
10. TA10.12: Building integrated **flexible lighting system using LEDs or OLEDs**;
11. TA11.3: **Harmonise test procedures and efficiency labelling schemes** to facilitate trade and transparency about the performances of energy using products;
12. TA12.2: **Standardised functionalities for sensors and actuators** to allow 'plug & play' of new devices (e.g. motorised shutters) and self-reconfiguration of sensor networks;
13. TA12.3: **Robust, resilient and reconfigurable sensor networks**;
14. TA12.4: **Building embedded sensors**;
15. TA12.6**: Interoperable smart meters** able to measure, record and visualise all kinds of energy consumption (incl. building generated energy supply, water and heat transfer fluids;
16. TA12.7: **Standard transmission protocols** to ensure reliability, security and privacy of data streams;
17. TA12.8: **User-centric interfaces** measuring the use value, with associated acceptance studies;
18. TA13.3: Development and demonstration of **Direct Current building electricity networks;**
19. TA13.4: **Modelling district energyy consumption and building interactions** for instance with Cloud computing;
20. TA13.5: **Demonstration of systems and protocols** to optimize energy storage and production at **district level**, involving possibly district energy market places and participation of large prosumers to local markets.

4.2.4 Other issues

It has to be noticed that in addition to the 40 projects that have been included in the technology building block WG there are 26 projects that have been assigned to this WG as second cluster, so it could be possible that some further research in the above targeted areas have been performed in such projects.

Projects included in Technology Building Block as 2° Technology Clusters	**1° Technology Cluster**
Buildsmart	Energy performance monitoring & management
CETIEB	
CITyFiED	
EINSTEIN	
ENRIMA	
FC-DISTRICT	
RESSEEPE	
S4ECoB	
SmartBlind	
Sporte2	
TIBUCON	
TRIBUTE	
AEROCOINS	Advanced Materials & nanotechnology
MF-Retrofit	
NANOPCM	
SESBE	
AMANAC	
ECO-Binder	
HomeSkin	
ISOBIO	
ENBUS	Design
NEXT-Buildings	
Insiter	BIM/Data/Interoperability
3ENCULT	Technology Building Blocks
EcoShopping	
READY	

Table 7 : WG Technology Building Block- projects as 2° Technology Clusters

5 Construction Process, End of Life and Cross Cutting information

5.1 Analysis of the scenario

Statistics forecast the value of worldwide construction industry at around USD 12 trillion by 2020. Today 40% of this market is represented by the residential buildings alone and it is expected to grow 4.5-5.5% globally by 2020. In Europe the residential sector alone, though expected to grow at a slower rate then globally, corresponds to approximately 43% of construction output. The construction sector is a crucial part of European economy, representing approximately 10% of its total GDP and providing 20 million jobs.

Technology innovations enhance the competition level of this sector demanding EU construction companies and actors to implement and integrate up-to date construction processes in order to maintain high European competitiveness in the sector. Construction Processes include a set of various elements such as: streamlined and improved processes, methods, organizational structure and operations. These advancements are paving the way for new ways of constructing buildings, and are strongly dependent on availability of new skills in the sector. New materials and energy sources along with new design approaches, advanced digital technologies and big data management are key drivers for new high-technology-content construction processes.

European standardization of the construction sector through the implementation of advanced euro codes together with important funding programs dedicated to the building retrofitting design and civil engineering works, represent a starting point for the risk reduction and harmonization in constructions. In fact the Eurocodes play a key role in the EU Commission's strategy to enhance European building companies' competitiveness in both euro markets and abroad. The Eurocodes are meant also to enhance and assure worker safety during construction process and are nowadays being implemented over national codes within member states. Last but not least the standards represent drivers for development and deployment of high-tech construction products and integrations.

Today's construction sites and processes feature a prominent use of advanced materials. However, basic building blocks of construction such as steel and concrete are still widely used throughout construction processes. Off-site fabrication and assembly, in other words modular construction, is a trend that has been clearly established.

In such framework the current challenges established at EU level encompass:

- Worker-centric construction processes are durable, adaptable, with better productivity and are able to cope with the increasing complexity of buildings;
- Quality driven construction processes;
- Lean Management of the construction process in particular in retrofitting case;
- Building deconstruction practices must evolve from demolition to selective

demolition and deconstruction/ dismantling, introducing novel solutions;
- The choice between demolition/deconstruction or rehabilitation must be based on informed decision-making processes;
- Research and innovation must be better linked to speed up the market uptake of promising solutions (= pre-normative research);
- Major social, demographic and climate evolutions by 2050 must be anticipated;
- The use value of buildings based on an in-depth understanding of users' behaviour must be scientifically assessed and taken into account over the whole building life cycle;
- A holistic optimisation framework is required to minimise CO2 emission, energy consumption and cost of ownership, where Life Cycle Assessment supports decision-making stage of the building value chain;
- The deployment of Building Information Models and Building Automation (BASCS) makes planning and realisation and utilisation of energy efficient solutions more cost-efficient and enables the engagement of constructors and manufacturers;
- Resource efficiency in buildings must integrate a district dimension with smart grids;
- The shift in mind set required for collaborative optimisation should be supported by innovative education and training techniques;
- Innovation processes dealing with the whole building value chain are able to facilitate the integration of novel technologies and construction processes.

Within the working group "Construction process, end of life, cross-cutting information", a total of 28 exploitable results had been documented and 13 have been validated with a TRL of 6 or higher.

Through the interviews, a total of 15 exploitable results has been validated with a TRL between 5 to 9. For 13 exploitable results the interview partners were not informed about the actual current status of activity implementations, therefore the TRL was stated with "no answer". Overall, 13 exploitable results were validated with a TRL between 6 and 9.

5.2 Target Areas Gap analysis

Starting from the work done within the Multi annual roadmap the Target Areas that could be directly associate to the Construction Process, End of Life and Cross Cutting Information are 30. Such targets have been matched with the EeB ppp projects and an assessment was performed ranking the target within three main groups as above explained.

5.2.1 Target Areas quite well addressed

The Target Areas considered quite well addressed are 2 as detailed below.

	FP7 PROJECTS				H2020 Projects
Targeted Areas	**Highly Promising**	**Promising results**	**Relevant results**	**Projects without validated results**	**H2020 Projects**
TA14.2	x			x	x
TA22.1		x			

Table 8 : WG Construction Process, End of Life and Cross Cutting Information Target Areas well addressed

In which:

1. TA14.2: Development of **standardised self-testing sensors/meters and performance verification procedures** (air-tightness testing, thermal survey with IR cameras and spectral imaging approaches, etc.);
2. TA22.1: **Full scale demonstration** of deep building refurbishment based on **mass customised envelopes** for the different building/construction types.

5.2.2 Target Areas partially addressed

The Target Areas considered partially addressed are 15 as detailed below.

	FP7 PROJECT		H2020 Projects
Targeted Areas	**Relevant results**	**Projects without validated results**	**H2020 Projects**
TA15.1	x	x	x
TA15.3		x	
TA16.1		x	
TA17.1		xx	
TA21.3		x	
TA21.4		x	
TA22.2	x	x	
TA22.3		x	
TA23.1		xxxxx	
TA23.2		xx	
TA23.3			x
TA23.4		x	
TA24.1	x	x	
TA25.1		xx	
TA25.4	X	xxxxxx	x

Table 9 : WG Construction Process, End of Life and Cross Cutting Information Target Areas partially addressed

In which:

1. TA15.1: Cost effective innovative **ICT-based technologies** (e.g. based on robust smartphones and tablets, cameras for 3D scanning, RFID, spectral imaging etc.) to **deliver building data in real time** to the workers involved in the construction process (model-based design and production planning integrating information flows across the value network, flexible project team management, contract configuration and management);
2. TA15.3: **Lean Construction Management** of refurbishment works, to improve communication among involved stakeholders, reduce costs and improve quality;
3. TA16.1: Cost effective innovative **automated/robotised construction tools** for refurbishing applications and new constructions;
4. TA17.1: **Training and education platforms** (using ICT-enabled tools) to provide certified construction training sanctioned by new skills evaluation processes;
5. TA21.3: Development of **construction materials and elements** (incl. prefabricate) containing a high level of **recycled materials** and recycled components leading to CO2 savings, energy savings and higher resource efficiency, which ultimately contribute to a resource-efficient and climate change resilient economy;
6. TA21.4: Development of **new materials and processes based on LCA/LCC** to account **for** environmental and sanitary **impacts of disassembling**: a) Environmental & health impacts of dismantling to be in LCC/CCA; b) materials and processes with no environmental/health impact and easy to disassemble;
7. TA22.2: **Decision tools** to choose refurbishment versus demolition processes **based on LCA/LCC optimisation**, addressing where relevant historical and cultural values;
8. TA22.3: Generic **building stock dynamic modelling** to optimise refurbishment roadmaps;
9. TA23.1: Collaborative **platform for concurrent building engineering** (design, construction, commissioning, service life, refurbishment, end of life);
10. TA23.2: **Optimal integration processes of components** and subsystems to reduce construction costs and risks;
11. TA23.3: **Envelope design tools** involving a dynamic multi criteria (incl. use value e.g. thermal, visual and acoustic comfort) optimisation of building integrated envelope, coupled **with HVAC**, to minimise the cost of ownership while enhancing indoor health and wellness;
12. TA23.4: **Probabilistic tools to model/predict the ageing performance** of complex refurbishment projects under European climatic conditions;
13. TA24.1: **Demonstrations of concurrent building** engineering which are sustainable and affordable (new building and refurbishment);
14. TA25.1: **Systems integration** from building to **neighbourhood level**;
15. TA25.4: Development of **a knowledge sharing platform** among

construction, energy and ICT stakeholders.

5.2.3 Target Areas not specifically addressed

The Target Areas considered not specifically addressed are 13 as detailed below.

1. TA14.1: **Techniques to measure** the contribution of each **critical component** to thermal insulation, air-tightness and building services equipment **in energy efficient construction**;
2. TA15.2: **Innovative construction processes** to provide workers with safer and healthier environments (for instance asbestos handling during refurbishment processes).
3. TA16.2: **Mobile factories** (portable manufacturing facilities, placed near the construction site);
4. TA16.3: **Tracking systems** (e.g. RFID, WSN, or with barcode/QR code etc.) for material and product implementation in new or existing buildings, including those of historical or cultural value;
5. TA17.2: Development and implementation of **builder certification schemes**, targeting construction SMEs;
6. TA21.1: **Waste collection, separation and reaction techniques** in order to increase the reuse of the building waste into recycled composites;
7. TA21.2: **Optimal re-usability or recyclability** of different types of products, including deconstruction;
8. TA23.5: **Probabilistic tools** to model/predict the **ageing performance** of zero energy buildings;
9. TA23.6: **Models and experimental tests** capable of **assessing the ageing** properties **of construction materials** and components (including envelopes);
10. TA24.2: Develop and disseminate innovations for the better **integration of the value chain in bridging the Single European Market with contexts of national laws;**
11. TA24.3 Review the mechanisms used in the various Member States in relation to energy labelling and its effect, develop an intelligent and well balanced **portfolio of mechanisms to raise public awareness**, **set regulations, codes and practices, fiscal and financial tooling;**
12. TA25.2: **Centralised application** able to **control parallel processes** done by different kinds of experts works in a project;
13. TA25.3: Development of **protocols and communications standards** that fit better with the needs of the vendors and the existing devices.

5.2.4 Other issues

It has to be noticed that in addition to the 22 projects that have been included in the Construction Process, End of Life and Cross Cutting Information WG there are 10 projects that have identified this second WG so it could be possible that some further research in the above targeted areas have been performed in such projects

Projects included in Construction Process, end of life, cross cutting information as 2° Technology Clusters	**1° Technology Cluster**
REViSITE	ICT
CITY ZEN	Energy performance monitoring & management
DIRECTION	
MODER	
SUS-CON	Advanced Materials & nanotech.
School of the Future	Design
RETROKIT	Technology Building Blocks
BERTIM	
E2VENT	
RIBuild	

Table 10 : WG Construction Process, End of Life and Cross Cutting Information projects as 2° Technology Clusters

6 Energy Performance Monitoring and Management

6.1 Analysis of the scenario

Eurostat together with other European institutions report with reference to Energy efficiency in buildings that 40% of EU's primary energy consumption derives from buildings and that buildings account for 36% of greenhouse emissions in the continent. In this sense the building sector has a central role in European Union's pursuit of 2020 energy goals. More precisely, since 2010 with the update of the Energy Performance Building Directive and subsequent Energy Efficiency Directive of 2012 the EU has made progress in trying to coordinate related regulation across the regions in order to create standards so to up-bring more favorable market conditions to the sector.

Both directives stand as a novel progressive model for Energy Efficiency globally and can be mapped to standards that address methodologies for conducting audits, and installing monitoring and measuring systems. The increased emphasis on Energy Efficiency related to buildings required the development and deployment of a new generation of high-tech accurate tools for assessing and managing, in real, time the energy performance both before and after building construction.

One of the most direct links between the regulations and real life applications is the obligation for companies of the building and or retrofitting sector to either perform facility-wide energy audits on a regular basis or set up an energy-management plan. The directive promotes the development and the implementation of high-tech monitoring and managing systems by exempting the companies that adopt them from annual audit requirements.

The EU has launched more than one hundred public financing mechanisms promoting energy efficiency in the building sector, (through FP7 and Horizon 2020 framework), most of which address already existing buildings requesting retrofitting deep renovation actions. However concerns have been raised over the nature of these financing programs that come in large scale as grants and subsidies and, for some, are not the most effective use of already limited public funds during a decade of economic down fall. In this sense financial institutions and EU banking institutions propose to use such dedicated budget to leverage more private finance instead.

In this framework the main challenges identified at EU Level are:

- Energy performance would be monitored steadily at the building and wider district levels over long period of times, combined with safety, security, comfort and any other monitoring system;
- The building and district energy performance is continuously optimized to meet performance criteria and evolving user's requirement and behaviour (including load forecast);
- Reduce the excess of unused, difficult to understand and not accessible information and data on real energy performance of buildings;
- Energy performance based contracts grow steadily;
- The actual performances of energy efficient buildings and districts are used as benchmarks by the construction sector for future constructions and refurbishments;

- Monitoring system commissioning and building continuous commissioning through the monitoring system.

6.2 Target Areas Gap analysis

Starting from the work done within the Multi annual roadmap the specific targets that Target Areas could be directly associate to the Energy Performance Monitoring and Management are 12 such targets have been matched with the EeB ppp projects and an assessment was performed ranking the target within three main groups as above explained.

6.2.1 Target Areas quite well addressed

The Target Areas considered quite well addressed are 8 as detailed below.

	FP7 PROJECTS				H2020 Projects
Targeted Areas	**Highly Promising Results**	**Promising Results**	**Relevant Results**	**Projects without validated results**	**H2020 Projects**
TA18.1	**xx**	**x**	**x**	**xxxxxx**	
TA18.3	**xx**	**xxx**	**x**	**xxx**	x
TA18.4		**xx**		**xxx**	x
TA19.1		**xxxx**	**xxxx**		
TA19.2.		**xx**	**x**	**xxxx**	
TA20.2	**xx**	**xxx**	**xxxx**	**xxxxxx**	
TA20.3		**x**	**xx**	**xxxxx**	
TA20.4	**x**	**xx**	**xx**		

Table 11 : WG 6 Energy Performance Monitoring and Management Target Areas well addressed

In which:

1. TA18.1: **Monitoring of envelope and energy equipment performances** in new or existing buildings (including those of historical or cultural value);
2. TA18.3: **Performance indicators** at European level allowing comparisons among regulations, user/client requirements, design models and real-life data, including end **user behaviour and end-user perception** (indoor environment including air quality, ventilation, lighting, etc.);
3. TA18.4: **Performance indicators** at European level allowing comparisons among regulations, design models and real life data **for district energy efficiency performance;**
4. TA19.1: **Development of self-diagnosis subsystems** (sensors and algorithms) leading to conditional maintenance improvement, based on LCC optimisation of subsystems (energy equipment, envelope) or systems;
5. TA19.2: Development of **virtual reality approaches** to make

diagnosis,maintenance and repair more efficient;

6. TA20.2: Development and **demonstration of energy performance monitoringsystems at district level;**
7. TA20.3: Development of **monitoring tools** able to **discriminate the contribution** ofdesign, technologies, construction process and user behaviour from the overallbuilding energy performance;
8. TA20.4: Development of **standard protocols** for ‘in vitro’ and ‘in vivo’ use-valuemeasurements of energy efficient building.

6.2.2 Target Areas partially addressed

The Target Areas considered quite well addressed are 3 as detailed below.

	FP7 PROJECTS		**H2020 Projects**
Targeted Areas	**Relevant Results**	**Projects without validated results**	**H2020 Projects**
TA18.2	**xx**	**xx**	
TA18.5	**x**	**x**	
TA20.1		**x**	

Table 12 : WG 6 Energy Performance Monitoring and Management Target Areas partially addressed

In which

1. TA18.2: Efficient and practical **means of measuring and monitoring the IEQ** (Indoor Environment Quality, including CO2 — as an indicator for air quality and triggering the air exchange rate — as well as global temperature, humidity, glare effects, VOC, SVOC, bacteria, fungi, etc.);
2. TA18.5: **Post Occupancy Evaluation** to standardise final user surveys and collecte data elaboration/presentation;
3. TA20.1: ‘**Wiki-like’ database** to report on R & D, demonstrations and real life results, dealing with energy efficient buildings.

6.2.3 Target Areas not specifically addressed

From the analysis performed only one target area seems not specifically addressed:. TA20.5: European network of use-value measurement laboratories.

6.2.4 Other issues

It has to be noticed that in addition to the 46 projects that have been included in the Energy Performance Monitoring and Management Information WG there are 29 projects that have assigned to this WG as second Technology Clusterso it could be possible that some further research in the above targeted areas might have been performed in such projects.

Projects included in Energy Performance Monitoring& Management as 2° Technology Clusters	1° Technology Cluster
IDEAS	ICT
TESSe2b	Advanced Materials & nanotech.
ZENN	Construction process, end of life, cross-cutting information
CAMPUS21	
E2ReBuild	
EeBGuide	
ee-WiSE	
EU-GUGLE	
GE20	
HERB	
NEED4B	
Rennovates	
R2CITIES	Design
CITYOPT	
H2SusBuild	Technology Building Blocks
A2PBEER	
BEEM UP	
BRICKER	
CommONEnergy	
InDeWag (EE)	
iNSPiRe	
MESSIB	
nanoCOOL	
SINFONIA	
BRESAER	
CREATE	
QUANTUM	
DREEAM	
ZERO-Plus (EE)	

Table 13 : Energy Performance Monitoring and Management projects as 2° Technology Clusters

7 BIM, Data, and Interoperability

7.1 Analysis of the scenario

Building Information Modeling is a relatively new concept that combines advanced software and dual displays in systems that allow designers, architects, engineers and clients to literally bring building information to life. Since 2014 BIM in the cloud technology has improved real time collaboration between construction professionals, accelerating the design while reducing errors and costs of the processes. In fact 2014 marks a milestone in the evolution and innovation of building technology. From smart roads to cloud computing, technology today helps every aspect of design and constructions grow. Essentially, BIM places information management and data exchange at the heart of the design process. BIM also continues to function long after construction is complete, becoming a system that maintenance engineers can interrogate to obtain specific information about individual components without having to directly view the parts.

Facts & Figures:

Today in the European Union Building information modelling is used as a process to help manage complexity and improve performance in construction projects. More specifically BIM as a software application allows users:

- 3D visualization of buildings: enabling construction teams to improve working among each other, with customers and subcontractors. This technology reduces design errors and allows faster modifications of final solutions.
- Change management: an automatic check of building structure alterations, identification of conflicts and quality improvement.
- Construction simulation: Try out different designs and optimize for the best cost-performance ratio while ensuring overall construction soundness and safety.
- Data management. Attach project data of many kinds (schedules, photos, scans of handwritten notes) to be able to find it all again in one place.
- Operational management. Check building performance (energy consumption for example) over the lifetime of a building and gain in efficiency in remodeling or extensions too.

BIM economic and technological value is recognized as a major force to drive both growth and increased competitiveness. The forthcoming EU Sustainable Construction Strategy has the potential to acknowledge that BIM will enable European construction companies to maintain their presence in global markets and internally to promote improved performance and an enhanced image of the sector. In parallel, the revision of the EU Procurement Directive is reviewing BIM. In this sense European BIM standardization is being established through the creation of protocols and regulations.

In fact many Euro Zone Countries have already adopted a “National BIM Adoption Strategy” that lay out the framework to increase use and adoption of BIM standards, a public client demand for BIM use, and a crucial role of data and standard use during maintenance phase of buildings and infrastructures. The BIM Technologies Alliance, that represents the BIM software industries, aims to work with Government and industry to embed existing BIM products and to develop more advanced products, data content and industry standards, protocols and procedures throughout Europe.

7.2 Target Areas Gap analysis

The Multi Annual RoadMap does not include BIM & Data Interoperability as an individual segment of the value chain; instead it reserves a dedicated Target area within the Design challenges and Target areas sections. Target area 3 of the Design segment establishes 5 specific targets that could be directly associated to the BIM & Data Interoperability. Such targets have been matched with the EeB ppp projects and an assessment was performed ranking the target within three main groups. As reported below the target areas well addressed and non adeguately addressed are not included since all the target areas have been evaluated partially addressed

7.2.1 Target Areas partially addressed

The Target Areas considered quite well addressed are 5 as detailed below.

	FP7 PROJECTS		**H2020 Projects**
Targeted Areas	**Relevant results**	**Projects without validated results**	**H2020 Projects**
TA3.1	**X**		
TA3.2			**x**
TA3.3	**X**		**x**
TA3.4;	**X**		**x**
TA3.5:			**x**

Table 14 : WG 6 BIM data and interoperability Target Areas partially addressed

In which:

1. TA3.1: **Enhanced BIM models** based on standardised energy efficient attributes and modelling of building energy profiles;
2. TA3.2: **Ontologies (**data models) to describe materials, equipment and technology interfaces typical of building and district projects;
3. TA3.3: Cost effective **BIM tools able to merge building models and building construction process management**;
4. TA3.4: **BIM control and certification methodologies**;
5. TA3.5: **Approaches** to enforce the **long term legal and contractual validity** of building information models.

7.2.2 Other issues

It has to be noticed that in addition to the 5 projects that have been included in the BIM data and interoperability WG there are 14 projects that have been assigned tothis WG as second Technology Cluster so it could be possible that some further research in the above targeted areas have been performed in such projects.

Projects included in BIM/Datra Interoperability as 2° Technology Clusters	**1° Technology Cluster**
BEEMER	ICT
EEBERS	
HESMOS	Construction process, end of life, cross-cutting information
CASCADE	Energy performance monitoring & management
EFFESUS	
SEEDS	
INDICATE	
COOPERaTE	Design
eeEmbedded	
HOLISTEEC	
STREAMER	
FASUDIR	
IMPRESS	Technology Building Blocks
MORE-CONNECT	

Table 15 : BIM data and interoperability projects as 2° Technology Clusters

8 ICT

8.1 Analysis of the scenario

The Multi Annual Roadmap does not include ICT as an individual segment of the value chain; instead it introduced ICT objectives within most target areas of the 6 Segments of the Value chain described.

During the assessment done in the previous phases of EEBCA2 only 3 projects were assigned to ICTas first technology cluster (IDEAS, REViSITE and EEBERS) but it has to be noticed that 37 projects have included ICT as second Technology cluster highlighting how even if no direct specific challenge is included in the roadmap some ICT research in under development.

Projects included in ICT as 2° Technology Clusters	1° Technology Cluster
MOEEBIUS	Energy performance monitoring & management
TOPAS	
HIT2GAP	
DESIGN4ENERGY	Design
New TREND	
Proficient	BIM/Data/Interoperability
Swimming	
OptEEmAL	
ICT4E2B	Construction process, end of life, cross-cutting information
Intasense	
READY4SmartCities	
UMBRELLA	
ACCEPT	
BUILT2SPEC	
AMBASSADOR	Energy performance monitoring & management
BEAMS	
BESOS	
CoSSMic	
DAREED	
DIMMER	
e-balance	
ECODISTR-ICT	
EEPOS	
EiT	
EPIC-HUB	
ODYSSEUS	
IREEN	
KnoholEM	

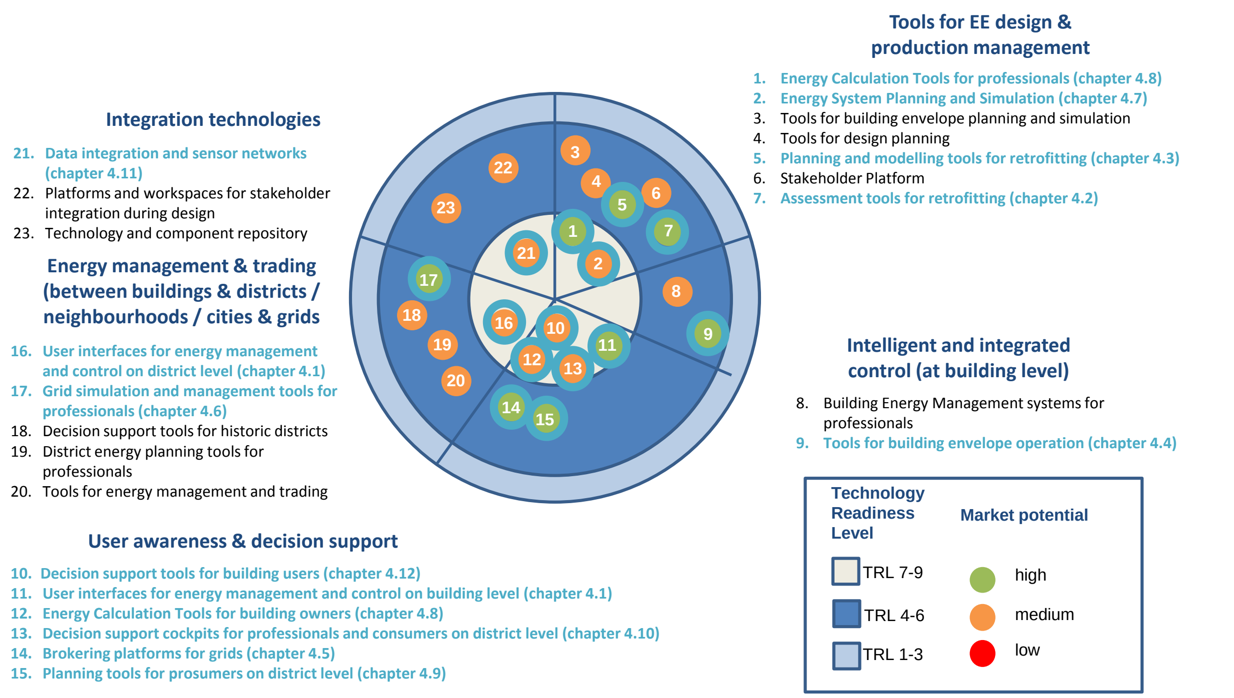
NewBEE	
NRG4Cast	
ORIGIN	
PERFORMER	
RESILIENT	
SEAM4US	
SEEMPubS	
SmartKYE	
URB-Grade	

Table 16 : WG ICT- project as 2° Technology Clusters

EEBERS focus is on identifying opportunities for synergies in ICT related RTD (Research in Technical Developments) in the EeB (energy efficient buildings) domain. This project has assessed the most relevant technological solution that has been identified clustered within 5 main areas:

- Integration technologies;
- Energy management & trading;
- Tools for EE design & production management;
- Intelligent and integrated control (at building level);
- User awareness & decision support.

11 technological solutions have been identified with a TRL 7-9 and have been deeply described in the outcomes of the project. For each of the most promising solution a customised deployment scenario have been developed as well.



EEBERS Deployment Scenarios

9 Advanced materials and Nano Technologies

9.1 Analysis of the scenario

European chemistry industry together with research and development in advanced materials and nano technologies, funded within the EeB PPP initiative, have created and deployed various significant solutions for energy saving/reduction in buildings most of which can be divided into five main thematic areas: reflective indoor coating, high reflectance and durable outdoor coating, phase change material (PCM), new insulation foam and other insulation modules.

Reflective indoor coatings optimize the use of natural and artificial lighting and can help maintain sunshine radiation heat inside during wintertime. High reflectance and durable outdoor coatings reflect sunlight radiation and can save up to 15% of air conditioning energy consumption. Phase Change Materials PCM are sold as active ingredients of various other semi-finished materials such as: plaster, cement, plasterboard and multifunctional wall and roof modules. PCM indoor use enables walls and ceilings to absorb and store excessive heat during the day, in order to dissipate it during the night. In recent tests, PCM has demonstrated a life expectancy of 30 years without loss of efficiency or performance. Advanced insulation foams with high performances can be adapted to different building's configurations, allowing high energy performance. It is estimated that foams can reduce the energy costs for heating by 30%-80%. Wall cavity insulation serves to fill the space between the two layers of the external wall of a building, in cases where no wall cavity is present; one can insulate the external walls of the building from the outside increasing the building's external thermal storage capacity, keeping temperature fluctuations acceptable. Vacuum insulation panel (VIP) modules avoid limiting design possibilities at the moment of refurbishing a glass façade of a building. Their insulation performance is some three times higher than conventional insulation materials. VIP module fragility and risk has been overcome by incapsulating the vacuum inside a double/triple and quadruple glazing package, allowing their use in glass-intensive building facades that need a strong improvement of their thermal insulation performance. These technologies provide long-term insulation performance with very limited loss of efficiency (20%) over the first 30 years of installed use.

The combination of these five technologies could on average result in overall energy savings, in heating and air-conditioning, of >40%. The exact amount of savings will depend very much on the type and location of the building.

In parallel according to Nanotechnology Products Database (NPD) January 2016 statistics, a total of 6,220 nanotechnology products are available on world market, produced by a total of 853 companies in 47 different countries. The construction sector alone includes a total of 667 nanotechnology products, produced by 149 companies in 28 different countries. Existing Nanotech products are classified in five industrial subsectors of structural materials, paint, coating, masonry materials, and chemicals.

One factor boosting the adoption of nanotechnology is an increase in the manufacture and availability of carbon nanotubes, a basic nanomaterial that can be used in a wide variety of manufactured goods.

Nanotechnology is helping to considerably improve, even revolutionize, many technology and industry sectors: information technology, energy, environmental science, medicine, homeland security, food safety, and transportation, among many others. Most benefits of nanotechnology depend on the fact that it is possible to tailor the essential structures of materials at the nanoscale to achieve specific properties, thus greatly extending the well-used toolkits of materials science. Using nanotechnology, materials can effectively be made to be stronger, lighter, more durable, more reactive, more sieve-like, or better electrical conductors, among many other traits.

Europe represents a leading innovation region in Nanotechnologies with excellent possibilities to take up the appropriate research and market challenges. Nanomaterials and Nano-chemical processes present relevant solutions for resource efficiency issues addressed by EU 2020 Strategy.

9.2 Target Areas Gap analysis

Starting from the work done within the Multi annual roadmap the specific targets Areas that could be directly associated to the 9 Advanced materials and Nano Technologies are 27 and they belong also to the technology building Block WG. Such targets have been matched with the EeB ppp projects and an assessment was performed ranking the target within three main groups as above explained.

9.2.1 Target Areas quite well addressed

The Target Areas considered quite well addressed are 5 as detailed below.

	FP7 PROJECTS				**H2020 Projects**
Targeted Areas	**Highly Promising**	**Promising results**	**Relevant results**	**Projects without validated results**	**H2020 Projects**
TA 6.1	**x**	**xxx**	**xx**	**xxx**	**xx**
TA 6.3		**x**	**xx**	**xx**	**xx**
TA6.6		**x**			
TA6.10	**x**				
TA8.7	**x**			**x**	

Table 17 : WG 6 advanced materials and nanotechnology Target Areas well addressed

In which:

1. TA 6.1: Development of innovative **super insulating materials and components**, and **associated manufacturing processes**, for refurbishing existing buildings (including those of historical and cultural value) and new buildings;
2. TA 6.3: **Improve technical properties** (e.g. fire resistance) f**or organic materials;**
3. TA6.6: **Low-CO2 advanced concrete** available for durable building envelopes;
4. TA6.10: Modular, 'plug and play', **mass customised envelope solutions** to ease construction processes and replacement of components (i.e. windows);
5. TA8.7: **Full scale demonstrations of adaptable envelope integration** in building refurbishment projects, including smart insulation materials (e.g. aerogels, vacuum insulation panels or other innovative materials).

9.2.2 Target Areas partially addressed

The Target Areas considered quite well addressed are 9 as detailed below.

	FP7 PROJECTS		**FP7 PROJECTS**
Targeted Areas	**Relevant results**	**Projects without validated results**	**H2020 Projects**
TA5.1	**x**	**Xx**	
TA6.2		**X**	
TA6.4		**X**	**x**
TA 6.5	**xx**	**X**	**xx**
TA8.1		**X**	
TA8.2	**x**	**X**	**xx**
TA9.1		**Xx**	
TA9.2		**X**	
TA9.3	**x**	**Xxx**	

Table 18 : WG 6 advanced materials and nanotechnology Target Areas partially addressed

1. TA5.1: Development of novel cost competitive high volume and high **performance eco-construction materials** (including cement, concrete, gypsum, glass, steel, FRP materials, wood, to name a few) to cost efficiently cut down CO2 emissions of the construction sector and associated with low embodied carbon and improved resource efficiency;
2. TA6.2 :New **value chains for bio-based construction materials** and bio-based **treatments** considering the complete life cycle;
3. TA6.4: Development of **chemical coupling agents and bindersor cooling;**

4. TA 6.5: New **masonry based building components** with integrated high-efficient insulation materials;
5. TA8.1: Development and manufacturing of **envelope improving and optimising natural light** and ventilation inside building;
6. TA8.2: Development and manufacturing of **energy storing converting materials** (e.g., Phase Change Materials and switchable glazing (e.g. thermochromic, photochromic or electrochromic) **combined with PV in glazing** panels);
7. TA9.1: **Smart building envelopes** capable of adapting their energy generation and storage to external condition;
8. TA9.2: **Integration** of existing and innovative **PV components** (e.g. OPV, DSSC) into building envelopes;
9. TA9.3: System **integration of 'thermally activated' material** to reduce energy consumption.

9.2.3 Target Areas not specifically addressed

The Target Areas considered not specifically addressed are 13 as detailed below.

1. TA4.1: Development of **strategies to identify economic construction procedures** for reuse of structures;
2. TA4.2: Development of **procedures to determine the structural load capacity** of existing structures accurately, which are easy to use and cost-efficient;
3. TA6.7: **Basement insulation, moisture protecting systems and new building materials for draining**;
4. TA6.8: **Mass manufactured prefabricated modules** for optimum cost, performance, product handling and personal safety during construction, both for new buildings and for refurbishing;
5. TA6.9: **Demonstration of photo-catalyst or other de-polluting materials** to extend the life of construction materials (with e.g. automatic cleaning process) and atthe same time substantially decrease the concentration of some air pollutants in urban air (COV, SOx, NOx), especially in confined spaces such as canyon streets, tunnels and parking;
6. TA7.1: **Technologies and methods to understand and maximise user acceptance** of adaptable envelopes in new and existing buildings (including buildings of historical and cultural value), addressing for instance air quality, moisture control, ventilation control or automated blinds, with interrelated issues of summer overheating, airtightness and indoor air quality;
7. TA7.2: **Techniques to minimise the Volatile and Semi-volatile Organic Compound** (VOC, SVOC) content of building materials (in the production phase and the use-phase);
8. TA8.3: Development of **semi permeable insulation membranes and pigments** with adaptable absorption reflection spectrum, **Façade component** with changing IR absorption and reflection on demand in combination with

insulation and switchable U-values;

9. TA8.4: New **testing procedures** to measure **material performances** (e.g. With reference also to adaptive performances), including a wide range of expectedexposure conditions;
10. TA8.5: Seamless system integration of **ICT components** used to **optimise the real time performance of envelopes;**
11. TA8.6: Improved flexible and durable **façade systems with movable sun barriers;**
12. TA8.8**: Full scale demonstrations of adaptable envelope** integration in district refurbishment project;
13. TA9.4: **Interaction with smart grid/city systems.**

9.2.4 Other issues

It has to be noticed that in addition to the 13 projects that have been included advance materials and nanotechnology WG there are 18 projects that have identified this second WG so it could be possible that some further research in the above targeted areas have been performed in such projects.

Projects included in Advanced Material & NanoTechnology as 2° Technology Clusters	**1° Technology Cluster**
ADAPTIWALL	Advanced Materials & nanotechnology
BRIMEE	Design
CLEAR UP	Technology Building Blocks
COOL COVERINGS	
EASEE	
ECO-SEE	
ELISSA	
EnE-HVAC	
FoAM-BUILD	
H-House	
HIPIN	
LEEMA	
NanoHVAC	
NANOINSULATE	
OSIRYS	
Winsmart	
LaWin	
HarWin	Construction process, end of life, cross-cutting information

Table 19 : WG Advanced materials and Nano Technologies project as 2° Technology Clusters

In addition to have further info on the impact generated by the project dealing with the advanced materials and nanotechnologies is possible to refer to AMANAC CSA project, AMANAC (Advanced Materials and Nanotechnology Cluster) is the cluster of all the Advanced Material and nanotechnology PPP-EeB projects under FP7. The cluster is an extension and further development of the Nano-E2B-Cluster, formed in 2011. It broadens the field of activities of the currently participating projects in a self-sustaining way

10 Monitoring and future priorities

A cooperation with the 2 other CSAs - EEbers and SWIMing – led to establishing a state of art of current practices, identification of challenges, future priorities and recommendations for each of the seven technology clusters identified in EeB-CA2.

For the specific cluster "*BIM/ Data / Interoperability*", the 2 other CSAs have developed additional reports further detailing the area of "BIM for renovation".

ENERGY EFFICIENT BUILDINGS

AN ECTP COMMITTEE FOR INNOVATIVE BUILT ENVIRONMENT

- **State of the art and current practice**
- **Challenges**
- **Future priorities and recommendations**
- **Impact**

Design	Technology building blocks	Advanced materials and nanotechnology	Construction process, end of life, cross-cutting information	Energy performance monitoring and management	ICT	BIM/ Data / Interoperability

Joint document prepared by the 3 H2020 Coordination and Support Actions:

EeB-CA2 Energy Efficient Buildings Cluster Activities Coordination Action

EEbers EeB ICT Clusters

SWIMing

Main author : Margherita Scotto (EeB-CA2)
Reviewers : Sara Van Rompaey (E^2ARC), Juan Perez (TECNALIA), Marc Bourdeau (CSTB)

Design

State of the art and current practice	Challenges	Future priorities & Recommendations	Impact
• Building design is developed with limited interaction with the value chain • Building design is a sequential process, doing the assessment of building performances just at the end, when project is fully detailed, but too late to make corrections • Energy efficiency is a design requirement "by law", but not an end-user demand • Energy efficiency is delegated to active system, without exploiting all the potential of passive solutions • Although CAD tools (2D) are common for architectural design, the use of CAE is limited to singular or emblematic buildings • Design decisions are mainly made based on the experience of the design team because it is very difficult taking advantage to the good practices developed in similar projects • Adoption of innovative products and building solutions is not common due to the associated risks and technical and financial uncertainties • Buildings are designed without taking into account the interaction with the district scale • Designers are progressively integrating environmental issues and more generally building life-cycle analysis in the design choices • Use of BIM is spreading amongst all types of stakeholders, including SMEs, and is starting to address not only large building projects. BIM managers are appearing on the scene, as well as BIM specifications for the building process • Increasing attention is put on the early design phase, where strategic decision is made, but ICT supporting tools are still lacking	• Design of energy/ resource efficient buildings (new or to be refurbished) must involve all stakeholders within a collaborative and risk share approach, allowing cost-efficient solutions from a LCA perspective • Development of Integrated Project Delivery (IPD): chosen project delivery methods can compromise the design. Integrated planning approach in renovation projects is a success factor for optimization and innovation with limited risks. Architects can coordinate all team members incorporating a wide range of disciplines (e.g.: cost estimation, project scheduling, construction supervising and safety regulations) • Performance prediction improvement: market and demand/supply structure, financial solutions and gap between expected and real building performance when renovating hinder the uptake of building renovation to satisfactory levels • Planning process improvement implies shared data, practices and tools with proper training and education • Decentralized and circular approaches for building and usage practices need to be considered at early design stage for an effective sustainability • Need to reduce cost of renovation in order to improve the financial return • Reduce the risk associated to the integration of new materials and building solutions • 5D Models: 3D + time + cost • Integration of the district scale in the building design • Provision of accessible, high quality and trustworthy data	**Development of solutions for new buildings and/or retrofitting projects** • Modeling and extensive simulation, exploring wider range of options for sustainability and/or optimization of energy performance versus cost/ROI is the future of EeB design • Methodology for holistic building design fully interoperable with simulation tools • Development of knowledge-based and performance-based early design tools • SW tool to select and compare products and components based on design, contextual and environmental requirements (location, standards) • Interoperability - data exchange protocols • Implementation of Innovative materials for a better and cost-efficient design – e.g. nanostructured materials like Aerogels • Accurate tools to assess the state and performance of the building before the intervention • Exploitation of repository of possible interventions and best practices • In the case of the retrofitting of historic buildings with heritage value, new methods for the involvement of the right actors like architects, urban planning and heritage authorities. • Innovative concepts for a systematic approach to retrofitting which integrates the most promising cost-effective technologies and materials with a maximum capacity of replication. • Decision support algorithms to find optimal solutions based on the users' weighing of economic and environmental (e.g. C02 emissions) criteria • Apps to monitor energy leading to decision support for retrofitting **Development of solutions at district level** • Tools for identification and selection of the most sustainable energy-efficient design and renovation strategies for urban districts • Optimised HVAC plus energy generation and storage • Open collaborative web platform sharing and integrating available data • Develop "smart grid ready" buildings	• Percentage growth of renovated building per year • Reduction of at least 60% in energy consumption in order to reach the target of near zero energy compared to the values before renovation, while enhancing indoor environmental quality • Considerable decrease of installation time compared to typical renovation process for the building type • Affordability considering all costs involved, with a payback period below 15 years • Increased energy class of the renovated building • Increased investment and turnover of the sector • Facilitated exchanges of information among involved stakeholders and innovative business models resulting in optimized design and cost reduction

Technology building blocks

Main author: Margherita Scotto (EeB-CA2)
Reviewers: Matti Hannus (VTT), Ilari Aho (UPONOR)

State of the art and current practice	Challenges	Future priorities & Recommendations	Impact
• Most energy harvesting sources are still little integrated within the whole building design and their impact on the aesthetical perception can represent a barrier to application • ROI of many available technologies to enhance energy efficiency is still too low; consequently appeal is lacking without complementary financing incentives • Technologies that focus on controlling solar heat gain, such as dynamic window films and dynamic windows, have high technical potential but current costs are limiting market penetration • Air-sealing technologies have currently limited capacity of concurrently regulating heat, air, and moisture flow • Lot of available sensors, connectivity technologies and cloud IT platforms, but a) not intelligently utilised in the building sector and b) not enough emphasis on how the eventual data collected from buildings and the building process can be used through analytics and big data approaches • Lot of research effort in new high performance materials but a very low level of commercial applications as of yet • Thermal storage solutions are available at single house level and could be up scaled at district level • Robust impact assessment methodologies are still missing for most technologies	• Energy efficient building envelopes are possible solutions to match the goals included in EU directives • Embedded RES, energy recovery in active envelopes are foreseen as the future trend in new building and building refurbishment • Application of material with high thermal insulation properties • Increase up to 35% the heat exchangers efficiency • Integrated procurement procedure, from design to commissioning enables the optimal choice and maximize the building envelope effectiveness for reducing the building energy demand • Integration of heating and cooling system, using renewable energy sources as ground thermal capacity for geothermal heating and for cooling, and sun for electricity production through PV • Deep and light renovation of buildings by attaching new insulated facades with the HVAC plants already assembled on it without requiring minimum connection time and minimum adaptation of the house plants	**Development of solutions for new buildings and/or for retrofitting projects** **Materials and envelopes** • Innovative materials - with ultra-high insulation capacity e.g. Nanostructured materials like Aerogels • Prefabricated elements containing the mechanical ventilation with heat recovery combined with heat pump and most of the main ducts • Energy harvesting materials • Nanotechnology coatings for improving heat exchanger efficiency • Prefabricated panels with high flexibility **Plant** • Thermal storage in low temperature heat networks • Heat pump to be used in refrigeration • Ventilation: intervention for heat recovery and optimized control • Deep Green Cooling (and heating) - ground used as source for cooling during summertime – restored during wintertime • Small scale bio-digester to be integrated in the basement of buildings for biogas production for domestic usages • Envelope component as thermal storage (use of ceramic/concrete etc.) **ICT support** • Monitoring systems for assessment of performances achieved and simulation models to evaluate performances • Sensor networks to monitor indoor quality parameters • Development of decision support tool to select best retrofitting options • Sensoring membranes for "hidden" monitoring in the components of the building (windows, walls, etc.)	• Deep renovation resulting in lower costs associated to improved efficiency • Simplification of building construction activities on the site • Better standardization of the building design • Improved indoor condition • Wall thickness reduction • Energy demand reduction • Integrated procurement for application within commercial buildings • Increased ratio of RES implementation

Advanced materials and nanotechnology

Main author: Margherita Scotto (EeB-CA2)
Reviewers: Gian Marco Revel (Università Politecnica delle Marche), Christian Artelt (HeidelbergCement)

State of the art and current practice	Challenges	Future priorities & Recommendations	Impact
• Advanced materials and nanotechnologies reside in the core of Energy Efficient Buildings • New eco-buildings need the application of innovative material • Various significant solutions for energy saving/reduction in buildings are in development clustered in: reflective indoor coating, high reflectance and durable outdoor coating, phase change material (PCM), new insulation foam and other insulation modules • Nano-materials are also applied to improve performance of HVAC systems	• Combination of different solutions in materials to reach 40% in energy savings, for heating and air-conditioning • Nanostructured materials barriers towards commercialization related to high manufacturing costs and to less mechanical stability in the field • Nanotechnology coating for heat exchangers that enhances efficiency about 25-35 % • Development of envelope solutions for considerably lighter modules with remarkably better thermal insulation values and increased lifespan • Circular Economy has to be implemented in the construction industry	**Development of solutions for new buildings and/or for retrofitting projects** **New reactive/adaptive envelopes** • Ultra-high insulation capacity for envelope application (aerogels and VIPs, including transparent facades) • Multi-functional ultra-lightweight concrete (insulation, loadbearing and other properties) • Ultra-thin glass membranes • Heat storage through the use of Phase-Change Material (PCM) • Energy harvesting with low-cost OPV • Ensures flame retardancy due to nanofillers and other solutions **Construction materials** • Durable and multifunctional material solution containing residue from other industry sectors and recycled materials o Total eco-sustainable concrete: combining the recycled aggregates with the recycled binders o Novel lightweight aggregates from plastics replacement of cement by secondary materials of high (aluminum-) silica content o Multifunctional materials combining aesthetics, comfort, health and energy efficiency • Nanotechnology coatings for heat exchange applications • Nanotechnologies for multifunctional lightweight construction materials • Development of low-embodied energy materials enabling circular economy **Development of solutions for districts** • Technology for reflective roof and walls increasing the efficiency at district level • Insulated pipes - reductions in heat losses in district heating distribution networks	• Energy demand reduction • Maximum use of passive solar fraction • Availability of eco-innovative and bio-renewable materials with an overall objective to reduce operational energy, in combination with the capability to avoid emission of harmful substances and to act as an absorber for indoor pollutants

Construction process , end of life, cross-cutting information

Main author: Margherita Scotto (EeB-CA2)
Reviewer: Juan-Manuel Mieres (SOLINTEL)

State of the art and current practice	Challenges	Future priorities & Recommendations	Impact
• Data collection is often difficult because it is nearly impossible to observe and record all details of ongoing construction work; hence, the current objective of any data collection technique is to approximate, as accurately as possible, what is taking place in the field • Lack of a continuous stream of data for analysis. Interoperable, cost effective solutions for quality driven management supported by innovative ICT are currently under development • Traditional construction delivery processes lead into a low productive industry. In most construction operational analyses, effective conclusions and decisions are severely limited by the lack of timely and accurate feedback information which describes actual operational data on the construction site. This also affects the accuracy of updating a project database; hence many critical decisions cannot be made in a timely manner • The construction of buildings involves the use of heavy equipment and oversized loads within the urban environment, creating significant environmental, safety and traffic problems with an important energy consumption	• The market needs a process which guarantees that in-service energy performances of building correspond to the designed performances • Continuous Quality Control is crucial to avoid errors compromising the durability of the building • Measures to ensure holistic performance (quality control, performances guarantee, business incentives, etc.) • New Quality driven construction processes, based on a simplification of assembling-disassembling techniques that include the use of multi-functional components and a reduction of loads and joints • Lean Management applied in construction process in particular in retrofitting case • Development of a Worker-centric construction process (durable, adaptable, with better productivity and are able to cope with the increasing complexity of building) • Building deconstruction practices must evolve from demolition to selective demolition and deconstruction/ dismantling, introducing novel solutions • The choice between demolition/deconstruction and rehabilitation must be based on extracting knowledge from building-related data and on informed decision-making processes based on performance & value • It is crucial to process the data collected in real-time cutting costs, boosting quality and reducing the time of analysis and time of response. • Simplification of the construction processes, reducing the large number of different systems that need to be put together and the large number of interfaces between elements	• Multidimensional methodology within the whole process of refurbishment where stakeholders collaborate to demonstrate successful methods for deep retrofit with the potential for large-scale replication • Diagnostic tasks integrated within "Performance Evaluation System", integrating Structural Health Monitoring and inspection tools when relevant (historic buildings, critical infrastructure etc.) • Continuous evaluation of energy and building services systems in an integrated way data imported from openBIM repositories using IFC4 • Creation of an optimisation algorithm for a set of solutions for a building at any stage in its life • Web-based decision-support application to allow users to identify, understand and visualise energy efficiency and reduction measures applicable to their building (at any stage of its life) and align these with optimised business models across the whole life of the building • Development and validation of new lean construction solutions driven by the reduction of dead construction loads, the deconstruction potential of new building systems and the increase on dematerialization of the processes • Validation of new technologies to improve capturing data from the field and transform them into useful information to build improved operational statistical models. New methodologies of transferring the location and time data into meaningful productivity information which requires the investigation of resource interdependencies within a construction operation • Solutions for the reduction of heat pumps consumption in borehole geothermal systems • Solutions for the reduction of the installation time of geothermal and sewage water heat pumps • Circular economy concept to join life cycle stages in most effective economic and sustainable fashion	• Holistic optimization frameworks will result in minimized CO_2 emission, energy consumption and cost of ownership • Life Cycle Assessment will support decision-making • Increased deployment of Building Information Models and Building Automation (BACS) • Resource efficiency in buildings integrating a district dimension with smart grids • Innovation processes dealing with the whole building value chain able to facilitate the integration of novel technologies and construction processes • Development of a circular economy based on a new construction market approach. • Improvement of the construction industry productivity, the quality and the value of its final products.

Energy performance monitoring and management

Main author: Margherita Scotto (EeB-CA2)
Reviewer: Antoine Aslanides (EDF)

State of the art and current practice	Challenges	Future priorities & Recommendations	Impact
• The energy performance of a building is rated considering building's design and conception	• Occupancy and end of life of a building must be accounted for to reach an overall energy performance rating	**Development of solutions for retrofitting projects and new buildings** • Interactive systems which allows accounting for works and refurbishment operations, as well as self-learning capabilities, to deliver a meaningful energy performance over the lifetime of a building • Guided natural light, LED technology & motion detectors with daylight compensation, advanced lighting controls • RES generation forecast, together with available storage capacities and related management • Solution for quantitative multi-dimensional comfort (and related health & well-being impacts) estimation and management	• Gap reduction between theoretical and actual energy and comfort performance of buildings • Stimulated eco-behaviours not only of the occupants but also of professionals from construction, operation and maintenance, facility managers and owners • Improved comfort and well-being • Development of a building performance ecosystem enabling synergies, cross-sector optimization and bringing down costs • Standardized data and interoperability between monitoring & control tools, favoring rational use of resources and enhanced energy efficiency
• Feedback on energy consumption is provided in real-time to the occupants	• Energy management must account for external signals in real-time (energy prices, energy grid operation, local energy generation, other fluids system, air quality, etc.)	• Move from an energy consumption to an energy efficiency vision, including comfort & health, delivering a situational meaningful performance estimation in real-time	
• Low cost sensors allow including operation & maintenance and environmental criteria into building automation	• Building automation must integrate data related to different stakeholders, from users to facility managers through maintenance crews	• Develop building automation systems aggregating data from all building stakeholders (incl. fluid networks operators) and applications (lighting, HVAC, heating, ventilation, water system, other commodities) • Standardize data to build open platform on which targeted application can be developed to address specific users / stakeholders (facility managers, operators, maintenance crews, intervention crews…) • Ensure interoperability between Building Automation systems (BAS) and Fault Detection and Diagnostics (FDD)	
• Energy is managed at building or individual house / flat level	• Building blocks allow more flexibility and rationale use of resources which underlines the need for integrated platforms ; • Coupling comfort and well-being with maximum efficiency	**Development of solution at district level** • ICT systems to support decision making when retrofitting a city district, optimizing planning (investment) and asset management (operation) • District Energy Management System, based on combination of predictive and self-learning algorithms, opening the way towards peer-to-peer exchanges • Decision Support Tool for Retrofitting a District, towards the District as a Service • Methods to compare energy performances of complex buildings	

Main author: Esa Nykanen (EEBERS)
Reviewers: Matti Hannus, Isabel Pinto (VTT)

ICT

State of the art and current practice	Challenges	Future priorities & Recommendations	Impact
• Advanced ICT tools, e.g. based on Building Information Modeling (BIM), are widely available. These are mainly aimed and used for new buildings • Interoperability of various systems and tools is improving. It is based on proprietary interfaces with limited access to tool/system specific semantics • Numerous data repositories are available (not yet mature enough). These typically provide data in fixed formats at low semantic levels • Basic web collaboration platforms are commonly used by construction project teams for data/file sharing, communication and informing the public • Automation, control and energy management systems are set up based on pre-existing conditions and require adjustments to remain up to date	• The ability of ICT tools to discuss with each other still continues to be a major long-term challenge • Unleash the potential of BIM technologies to integrate processes for building retrofitting, operation and maintenance • Enable effective use of available data from different sources, with different formats and semantics to support the individual needs of different stakeholders and end users • Support inter-company workflows, energy trading, co-creation and involvement of all stakeholders including end-users and citizens	• Develop and promote common platforms for collaboration, coordination and co-creation, data exchange standards and flexible interfaces to serve information sharing between stakeholders involved in various stages of the building life cycle • Develop and integrate approaches for modelling of existing buildings using e.g. data linking, 3D scanning, infrared imaging, drones, sensors etc. to support the refurbishment process • Create tools that can use data from different sources in formats and at different semantic levels • Develop algorithms for proactive prediction of energy consumption, production & pricing, weather conditions, usage patterns and maintenance & renovation needs • Develop open databases of materials, products, technologies, services, historic construction solutions (for renovation) and current best practices with flexible interfaces to deliver data to users in customized ways • Develop applications of social networks to support engagement of citizens in urban developments and their activities towards energy efficiency & sustainability • Develop easy-to-use multi-functional ICT tools to end-users for managing various functions of their (smart) homes e.g. energy efficiency and assisted living • Development of shared ICT tools supporting both Energy Efficiency and Active Assisted Living & Healthy Ageing	• Access to versatile relevant data leads to improved energy efficiency • Reuse of proven solutions promotes industrialized construction and leads to reduction of errors and quality problems • Open data creates opportunities for new competitive advantages, business models and services • Empowerment of stakeholders and end users leads to better optimized solutions and greater satisfaction by all • Proactive smart buildings requiring less human interventions while increasing comfort

BIM/ Data/ Interoperability

Main author: Matthias Weise, Kris McGlinn (SWIMing)
Reviewer: Matti Hannus (VTT)

State of the art and current practice	Challenges	Future priorities & Recommendations	Impact

• BIM is accepted as a solution for issues related to interoperability, main focus is on new design
• File-based data exchange still dominating (BIM level 1 and 2)
• Design coordination and reuse is focused on clash detection; other types of data quality control still require significant manual efforts
• Data is stored in many independent data formats and systems based on different technologies (SPF, XML, CSV, etc.)
• Data is converted back and forth between data formats leading to information losses
• Lack of BIM data (BIM is often missing or not in required quality)
• BIM is still new to many users in the industry
	• Transfer fragmented BIM workflows to integrated design (increase reuse and sharing of data)
	• Improve BIM quality by providing checkable data exchange specifications
	• Increase BIM experiences of users
	• Reduce the risk of vendor lock-ins by "Closed BIM" solutions
	• Shift focus from design to other BLC stages, in particular renovation and operation
	• Providing data which is accessible, high quality and trustworthy in particular in renovation scenarios
	• Agree on solutions for Linked Building Data, i.e. how to manage data that is stored in different data sources
	• Strategy for publication and long-term preservation of BIM data
		• Promote the use of "Open BIM" standards (strengthen standards like IFC, CityGML, SAREF and more use case focused ontologies like SSN, gbXML, SIM Model, etc.)
		• Improve interoperability by coordinating research in the following areas:
		  o Extension of existing standards to deal with new requirements
		  o Provide methods to support implementation and use of those standards, e.g. by establishing automatic data quality checks, simple examples etc.
		  o Solutions to configure and generate well-document BIM workflows, e.g. to derive responsibilities and support end-user guidelines
		• Methods to increase availability of high-quality BIM data, e.g. to derive from available documents and new data collection methods (e.g. laser scanning)
		• Solutions to preserve created BIM data and to make it available to other services in the operation phase
		• Research on solutions for integrating different data sources, including research on co-existence of BIM with other data schemata/ontologies
		• Clarify the role of BIM in Linked Building use cases
		• Make information about Linked Building Data more easily accessible for example by offering a repository about use cases, available (open) standards and open datasets
			• Open standards enable the selection of best in class tools and opens the market to new, innovative "downstream" services
			• Improving the quality of exchanged BIM data (completeness, consistency) – is an essential prerequisite for high quality simulations and reduced data management efforts
			• Increased availability of high-quality data of existing building stock
			• Linked Open Data enables more holistic simulations of our buildings to find best solutions

11 Conclusion

The aim of this report is to present the monitoring methodology developed and implemented exploiting available data collected through the EeB PPP monitoring questionnaire (circulated in April 2015) and stored in the EeB-CA2 Knowledge Platform.

The first periodic reporting of FP7 project activities and results, taking into account scientific potential, technology readiness advancement for facilitating market uptake for innovative solutions developed in the context of EeB PPP projects is released to support third-parties initiatives or to EC itself in order to guarantee continuity of the monitoring process.

Seven technology-clusters (Design, Technology Building Blocks, Advanced Materials & Nanotechnology, Construction Process; End-of-life & Cross-cutting Information, Energy Performance Monitoring and Management, ICT, and BIM, Data; Interoperability) with different positions in the construction-related research and innovation value chain from the EeB Roadmap have been defined and analysed.

The Gap analysis has provided for each of the above mentioned cluster and assessment of the achievements within the target areas as defined in the multiannual roadmap.

The aim was to identify areas that have been addressed well or partially and areas where the research activities performed in the framework of EeBPPP are not yet exhaustive.

Further development have been done to detail and monitor WG per WG:

- State of the art and current practice
- Challenges
- Future priorities and recommendations
- Impact

The information has been selected exploiting the outcomes of the technology assessment done, of the monitoring activities and of the gap analysis.

Such work has been also reviewed by experts of the ECTP network as detailed WG per WG.

For each WGs the most relevant target areas addressed could be summarized as follows:

WG Design: project supported in such framework aimed to develop design tools based on: model-based CAD approaches and interoperable interface; improved design accurancy applied with demo districts with the engagement of different stakeholders and on libraries of reference integrated within the tools themselves.

WG Technology Building Blocks. The projects supported in the framework of this WG best addressed the development and integration of: super insulating materials and components; improved technical properties for organic material; tools and methods to maximize user acceptance of adaptable envelopes; techniques to minimize Volitile

Organic Compound (VOC, SVOC); envelopes improving natural light and ventilation in buildings and full scale demonstrations of adaptable envelope integration; smart building envelopes; innovative PV components; building and district level thermal storage; heating systems and storage at building and district levels; heat and power systems at building and district level; low GHG refrigerants; benchmarkinbg and calculation tools; sensors and smart consumption displays for BEMS.

WG Construction Process, End of Life and Cross Cutting Information. The projects supported in the framework of this WG best addressed the development and integration of: standardize self-testing sensors/meters and energy performance verification procedures; full scale demonstration of deep building refurbishment based on mass customized envelopes.

WG Energy Performance Management and Monitoring. The projects supported in the framework of this WG best addressed the development of: monitoring tools for envelope and energy equipment performance; legal/societal/environmental performance indicators at EU level; self-diagnosis subsystems for conditional maintenance; virtual reality approaches to diagnosis; energy performance monitoring systems at district level; monitoring tools able to discriminate additional criteria from overall building energy performance; standard protocols for use-value measurements of energy efficiency in buildings.

WG BIM, Data and Interoperability The projects supported in the framework of this WG, focus on: developing enhanced BIM models and ontologies to describe interfaces of building and district projects; BIM tools able to merge building models and construction process management and relative control and certification methodologies; approaches to enforce long term legal and contractual validity of BIM.

WG ICT. The projects supported in the framework of ICT WG, as described in detail in EEBERS project, focus on identifying opportunities for synergies in ICT related RTD (Research in Technical Developments) in the EeB (energy efficient buildings) domain. The most relevant technological solutions assessed by EEBERS project have been identified and clustered within 5 main areas: Integration technologies; Energy management & trading; Tools for EE design & production management; Intelligent and integrated control (at building level); User awareness & decision support.

WG Advanced Materials and Nano Technologies. The projects supported in the framework of this WG best addressed the development of: super insulating materials and components; improved technical properties for organic materials; advanced low CO2 concrete; modular mass customized envelope solutions and full scale demonstrations of adaptable envelope integrations.

At the same time for each WGs the target areas that have not specifically addressed could be summarized as follows:

WG Design: this WG still need to address the definition of approaches to enforce the long term legal and contractual validity of building information models.

WG Technology Building Blocks: this WG still need to address some areas as: the easy use and cost efficiency of procedures to determine the structural load capacity of existing structures accurately; some material related aspects such as: the Development of chemical coupling agents and binders; Low-CO2 advanced concrete, materials for draining; Mass manufactured prefabricated modules, flexible lighting system using LEDs or OLEDs. Some demo and testing aspects related to: photo-catalyst or other de-polluting materials to extend the life of construction materials, demonstrations of adaptable envelope, modelling district energy consumption and building interactions systems and protocols to optimize energy storage and production at district level, new testing procedures to measure material performances, harmonize test procedures and efficiency labelling schemes. Some monitoring aspects such as: standardized functionalities for sensors and actuators, robust, resilient and reconfigurable sensor network: building embedded sensors; Interoperable smart meters.

WG Construction Process, End of Life and Cross Cutting Information. this WG still need to addressed some areas such as: techniques to measure the contribution of each critical component in energy efficient construction; the development of innovative construction processes to provide workers with safer and healthier environment and also systems to control in parallel works done by different experts; mobile factories composed by portable manufacturing facilities, placed near the construction site and tracking systems; waste collection, separation and reaction techniques in order to increase the reuse of the building waste into recycled composites and optimal re-usability or recyclability of different types of products; probabilistic tools to model/predict the ageing performance of zero energy building,: models and experimental tests capable of assessing the ageing properties of construction materials and components; comparison among member state in relation to energy labelling and its effect, develop an intelligent and well balanced portfolio of mechanisms to raise public awareness, set regulations, codes and practices, fiscal and financial tooling.

WG Energy Performance Management and Monitoring. With this WG the target areas that still need to be addressed is related to the enlargement of European network of use-value measurement laboratories.

The **WG BIM, Data and Interoperability a**nd **ICT** as described in the report this two WGs have been treated in a special way due to the fact that they are not directly included as segment of the roadmap. The area could be linked to the area BIM and ICT have been therefore all quite well or partially addressed.

WG Advanced Materials and Nano Technologies this WG still need to addressed some areas such as: the development of strategies to identify economic construction procedures for reuse of structures and procedures to determine the structural load capacity of existing structures accurately, which are easy to use and cost-efficient; technologies and methods to understand and maximise user acceptance, testing procedures to measure material performances, ICT components used to optimise the real time performance of envelopes, façade systems with movable sun barriers; basement insulation, mass manufactured prefabricated modules; the demonstration of photo-catalyst or other de-polluting, techniques to minimise the Volatile and Semi-volatile Organic Compound semi permeable insulation membranes and pigment.

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