Towards a New Advanced Industry for an Energy Efficient Built Environment

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Abstract

The key objective of the Energy Efficient Buildings Association (E2BA), representing a large set of stakeholders of the construction sector and associated technology sectors, is to promote the creation of an active industry for the production, supply/distribution of advanced systems, solutions and added value services with a view to satisfy the needs on energy efficiency for the built environment.

The Association is engaged since 2009 in a Public-Private Partnership on Energy-efficient Buildings (PPP EeB) with the European Commission (EC) to develop and deploy a full Research, Development and Innovation (RDI) program at EU level. As a matter of fact, buildings provide a large untapped cost effective potential for energy savings, but in order to speed up the deployment of key technologies at least cost, it is crucial to increase innovation in the fields of energy efficient construction processes, products and services.

The paper includes a brief presentation of the main results of the tenths of collaborative trans-national RDI projects launched in the framework of this PPP. Some of these results are already available and disseminated by the projects; some of them are still under development. It is also dedicated to the presentation of the new Roadmap recently prepared by the Association in cooperation with the EC, containing the major RDI challenges faced by the sector by 2020 to meet the EU decarbonization goals.

Keywords: energy efficiency, buildings, districts, smart cities

1. Introduction

Worth at least 1.3 trillion Euros of yearly turnover in 2010, the European building sector and its extended value chain (material and equipment manufacturers, construction and service companies) is on the critical path to decarbonize the European economy by 2050. It must enable reducing its CO2 emissions by 90% and its energy consumption by as much as 50%. This is a unique opportunity for sustainable business growth provided that products (new or refurbished buildings) and related services are affordable and of durable quality, in line with several past or future European Directives. Yet, together with the 2050 deadlines, such Directives are putting more constraints onto a sector which is directly impacted by the on-

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going financial and economic crisis (less purchasing power, but also potentially increasing building costs due to more stringent requirements to meet building energy performances). The time frame left to develop innovative technology and business models in line with the 2050 ambitions is narrowing down to less than 10 years.

2. The running Public Private Partnership on Energy-efficient Buildings (PPP EeB)

The running PPP EeB was launched as part of the economic recovery plan in 2008. The PPP EeB uses existing mechanisms of the Framework Programme of the European Commission (EC) whilst providing a mid-term approach to R&D activities. It brings together various Directorates Generals (DGs): DG Research and Innovation - Nano, Materials & Processes (NMP) and Environment (ENV) priorities -, DG Energy, and DG Communications Networks, Content and Technology, in close dialogue with industry. In this framework, a roadmap was built on the following pillars, namely: 1) systemic approach; 2) exploitation of the potential at district level; 3) geo-clusters, conceived as virtual trans-national areas/markets where strong similarities are found, for instance, in terms of climate, culture and behaviour, construction typologies, economy and energy/resources price policies, Gross Domestic Product, but also types of technological solutions (because of local demand-supply aspects) or building materials applied etc.

These pillars are definitely brought forward in a new Research and Innovation Roadmap (to be published in 2013) which indeed is strongly based on the long term programme defined by the PPP EeB (2010) around a "wave action". In this "wave action" plan, continuous, on-going research feeds successive waves of projects as shown in Figure 1. The knowledge gained in the first "wave" feeds in the second at the design stage, realising a continuous implementation process.

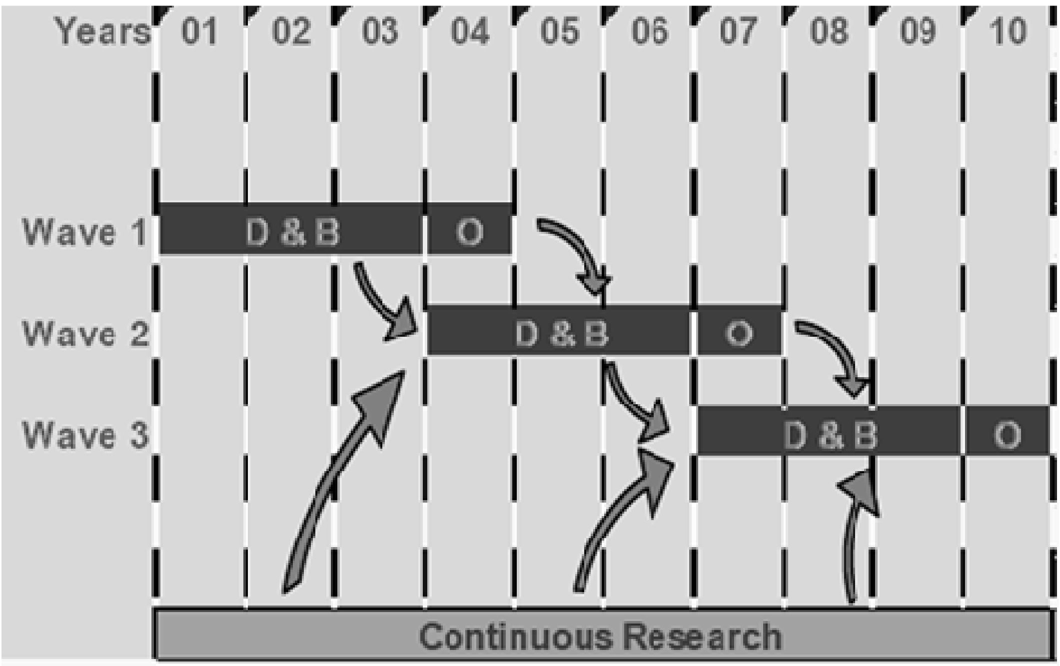

Figure 1: Wave action along the roadmap (D&B: Design&Building; O: Operation)

As a result of this “wave action”, industry expects to reach impact following a stepped approach, namely:

- Step 1: reducing the energy use of buildings and its negative impacts on environment through integration of existing technologies (main focus of the current PPP EeB);

- Step 2: buildings cover their own energy needs;

- Step 3: transformation of buildings into energy providers, preferably at district level.

The long term programme set by industry tackles also the development of those enabling knowledge and technologies which are instrumental to achieve these targets, launching the required more fundamental and applied research actions. This long term approach has mobilised heavily industry with over 50% participation in calls and Small and Medium size Enterprises (SME) involvement beyond 30%, figures which are well above business as usual in collaborative research projects under the EC framework programme.

Reviews by E2BA (2011, 2012) of the different running projects have highlighted some of the innovations under development, such as:

- Nanotechnology coatings
- Integrated air quality sensors
- Tools to improve indoor environment
- Operational guidance for performing Life Cycle Assessment (LCA) studies
- Sustainable, innovative and energy-efficient concrete
- High performance bio-composites for buildings
- Component and systems for buildings, such as multi-functional façade panels
- Components and systems for districts, such as energy storage solutions
- Standardized building and user friendly models
- Energy control hardware
- Building Energy Management Systems (BEMS)
- Heating Ventilation and Air Conditioning (HVAC) control systems
- Energy performance simulation
- Virtual building models
- Integration of multifunctional energy modules
- Business models.

3. Overall vision till 2030 and strategic objectives

3.1 Vision 2030

Based on the achievements so far, the E2BA ambition is to drive the creation of an innovative high-tech energy efficiency industry extending the scope of the running PPP EeB beyond 2013. Connecting construction industry to other built environment system suppliers will be the decisive step for Europe to reach its economic, social and environmental goals, contributing to the objectives of the Innovation Union. By creating and fostering this paradigm shift, EU companies will become competitive on a global level in the design, construction and operation of the built environment while sustaining local economies across EU-27 through job creation and skills enhancement, driven by the vast majority of SMEs active in the value chain.

In line with ambitious 2050 targets, it is expected that already in 2030 the entire value chain will produce advanced systems, solutions and high value services for intelligent and sustainable buildings and districts. The long term strategic objectives defined by E2BA (2012) include:

- Most buildings and districts become energy neutral, and have zero CO_2 emission. A significant number of buildings would then be energy positive, thus becoming real power plants, integrating renewable energy sources, clean distributed generation technologies and smart grids at district level.

- Industry will employ highly skilled individuals capable of efficiently, safely and quickly carrying through construction processes. This means an extended value chain and collaborative "assembly" line delivering adaptive and multifunctional energy and resource efficient buildings and districts solutions.

- Unemployment will be kept low as skilled local jobs will be created through an effective and dynamic matching of demand and supply. Public Private Partnerships will indeed cover the entire innovation chain, fostering performance based contracting and innovation friendly procurement practices. This will be achieved with sustainable financial incentives schemes on the demand side. On the supply side, systemic technical solutions optimised at European scale will be integrated locally.

- Urban planning and smart cities implementation leverage on these novel solutions at building and district scale, creating the basis for intelligent connections between buildings and districts and all urban resources.

- Such globally competitive energy efficiency industry will be able to deliver new business opportunities, jobs and solutions. In terms of environmental impacts, greenhouse gas emissions will be reduced to 80-95% below 1990 levels, as required by the Energy Roadmap 2050 (COM(2011) 885/2). In addition, the use of renewable energy and efficiency technologies is extended as required by the Strategic Energy Technology Plan, the Energy Efficiency Plan and the recast of the Energy Performance of Buildings Directive (EPBD).

Indeed in Europe, each Member State with its own building stock is faced with a combination of four implementation options to comply with the challenges ahead, inevitably mixing rehabilitations and construction of new buildings:

- Option 1: increase significantly the rate of high performance, deep rehabilitation of commercial and residential buildings, while lowering the costs of rehabilitation.

- Option 2: increase the overall depth of rehabilitation by favoring district rehabilitation in priority.

- Option 3: valorise energy production and use within new districts to make these districts “energy positive”.

- Option 4: scrap all poorly insulated buildings and replace them by high performance buildings (energy neutral and, when possible, energy positive).

Member States have a reduced set of optimization parameters to address properly these options:

- the spatial scale chosen for energy demand optimization (single building versus district); the district dimension provides new energy optimization possibilities, for instance through the connection to existing grids (electricity, heat and cooling networks), via the design and operation of a set of buildings as components of an integrated energy system, which can in turn contribute to improved peak load management.

- the rate of new constructions versus the rate of refurbishment which in turn is conditioned by:

    - the depth of refurbishment versus the new building energy performance level (set by law)

    - the split between technology-based (energy demand) and behaviour-based (energy use) solutions, whatever the project under scrutiny.

Implementing pathways at the right pace to make innovation breakthroughs possible requires the building sector to go through a profound mutation before 2030 which shape a vision as described below:

<u>Vision 2030</u>

By 2030, increased and faster collective research and innovation has allowed the European building sector to mutate into a mature, innovative and energy efficient enabling industry:

- delivering new or refurbished, user centric and affordable buildings/districts in line with EU2020 and national strategic objectives and commitments towards 2050;
- working according to quality standards that encompass the whole life cycle of any building, thus guaranteeing durable building performances;
- valuing not only energy performances but also aesthetics, acoustics, accessibility or comfort as purchase criteria for end users;
- committing to long term performance guaranteed contracts on the energy bills.

In doing so, industry aims at introducing as most technology and market flexibility as possible for the benefits of policy makers and investors when facing the decarbonisation of the building sector. Any mix of the above four scenarios can then be addressed by the building industry in the next 40 years, industrial maturity being reached by 2030.

3.2 The critical role of refurbishment

Tackling refurbishment of existing building is a top priority; it is expected that, by 2050, about half of the existing building stock in 2012 will be still operational. BPIE (2011) emphasized the critical role of refurbishment, when considering various pathways to achieve the 2050 building sector decarbonisation goals. The proposed pathways differ from one another by:

- the speed at which buildings are refurbished (the refurbishment rate),
- the level of energy or greenhouse gas emission savings that are achieved when refurbishing a building (the refurbishment depth).

The BPIE study developed five scenarios that may or may not achieve the 2050 target for the building sector: only two work well –the Deep Scenario and the Two-Stage Scenario. When comparing these two scenarios with the current situation, it can be seen that:

- both rate and depth of refurbishment must at least double and even triple, compared to the currently observed situation,
- the depth of refurbishment must start increasing before 2020 to avoid the need for a two-stage refurbishment process, which in turn would yield a higher share of zero energy buildings by 2050.

Nevertheless, the BPIE study has not addressed the impact of a third critical parameter: the **district dimensions** which could possibly relax either one of the above trajectory parameters and **innovation**, since allowing for cross building energy cooperation and/or smart energy generation and use within districts. At any rate, deep refurbishment will be required, meaning:

- breakthrough technological and economic performance improvements for the building envelope (reduce the demand);
- proper downscaling/management of energy equipment (adjust to a lower demand without losing energy use efficiency);
- durable performance improvements (avoiding user’s misuses and/or building disorders).

Another relevant aspect not considered is this report is the associated investment to these scenarios. Research and innovation are clearly needed to reduce the huge additional investment required to reach the renovation targets in terms of energy efficiency, which are measured over 60 billion € additional investment per year. Finally, a last aspect which the paper does not include but may hinder innovative and energy efficient refurbishment is represented by the large number of micro and small enterprises involved in the refurbishment operations: it is well known the uptake of innovative technologies by SMEs is rather slow due to limited economical and knowledge resources.

4. Research and Innovation Strategy

4.1 Methodology

The preparation of the EeB Roadmap has been driven by industry in the framework of the Ad-hoc Industrial Advisory Group set-up within the running PPP EeB. The private sector is represented by the European “Energy Efficient Buildings Association” (E2BA), as industrial interlocutor of the European Commission in the PPP EeB.

The scope of the Roadmap was indeed to update the research and innovation priorities to align the industry long term plans with the content of the next EC RDI Framework Programme “Horizon 2020” proposal, where a clear research line on “Technologies for Energy efficient Buildings” has been proposed by the EC. In this framework an extensive review of running research and demonstration projects and major initiatives at EU scale such as the SET Plan (including the recent Roadmap on materials enabling low carbon energy technologies), the Smart Cities European Innovation Partnership, the Intelligent Energy and Eco-innovation programmes under the CIP framework, the InnoEnergy Knowledge and Innovation Community (KIC) running under the European Institute for Innovation and Technology (EIT), the Lead Market initiative and recent Communication on “Sustainable Construction” by DG Enterprise as well as the Energy efficient roadmap and consultation on “Financial support for energy efficiency in buildings” by DG Energy, to name a few. Inputs and contributions from key stakeholders have been mobilised within the framework of the ICT4E2B Forum (www.ict4e2b.eu) and Building-Up (www.buildingup-e2b.eu) projects gathering experts from construction, energy as well as ICT domains, and relevant European Technology Platforms (i.e. European Steel Technology Platform (ESTEP), Forest-Based Sector Technology Platform (FTP), European Technology Platform for Sustainable Chemistry (SusChem), European Technology Platform for Advanced Engineering Materials and Technologies (EUMAT), European Technology Platform for the future of Textiles and Clothing). They have been complemented by inputs and feedbacks received within an open consultation launched in early July 2012 and closed on October 1st 2012.

The innovation rationale proposed by industry is to extend the ambition of the running PPP EeB beyond 2013 in line with the 2030 vision to develop and to validate a set of innovative integrated to novel tools, technology and process components covering the whole value chain. They will then be integrated to meet future market conditions, thus:

- transforming barriers and regulatory constraints into innovation opportunities,
- fostering the creation of innovative supply chains, that become more user centric to cope with the difficulty of implementing refurbishment strategies,

- reorganizing and stimulating innovative procurement of buildings and ordering of technology/services with the integration of new smart grids technologies for single buildings as well as for whole districts (new buildings and existing stock).

Today's fragmented nature of the construction chain still gives little freedom for innovations that are indispensable to shape a more sustainable built environment. Yet, collaborative project management in the construction sector has become a prerequisite to develop a building stock that is technically and economically optimized: this goes against centuries of working habits. Moreover, the focus must be on creating value (not only in terms of economics, but also in terms of comfort, health, environment, etc.) for all the users involved. This requires new skills together with a major behavioural shift within the entire construction sector. Coalitions must be given birth, dedicated to collaboration between players from different disciplines to contribute to the realization of buildings with energy-ambitious goals.

The whole value chain (see Figure 2) will be involved in this continuous optimization process which follows three major steps:

- Step 1: From design to commissioning of new or refurbished buildings, the optimization consists in picking amongst a portfolio of material and energy equipment solutions, the ones which meet both a cost of ownership target and minimal potential GHG emissions over the foreseen life cycle.

- Step 2: During this life cycle, robust user-centric energy management systems ensure that the initial GHG emissions targets are continuously met thanks to adaptive energy management tools able to correct for or modify behaviours of users. Only natural ageing of technology can impact the initial energy performance at commissioning.

- Step 3: The next refurbishment involves another optimisation approach where the investment for refurbishment can be recovered through further savings on the cost of ownership.

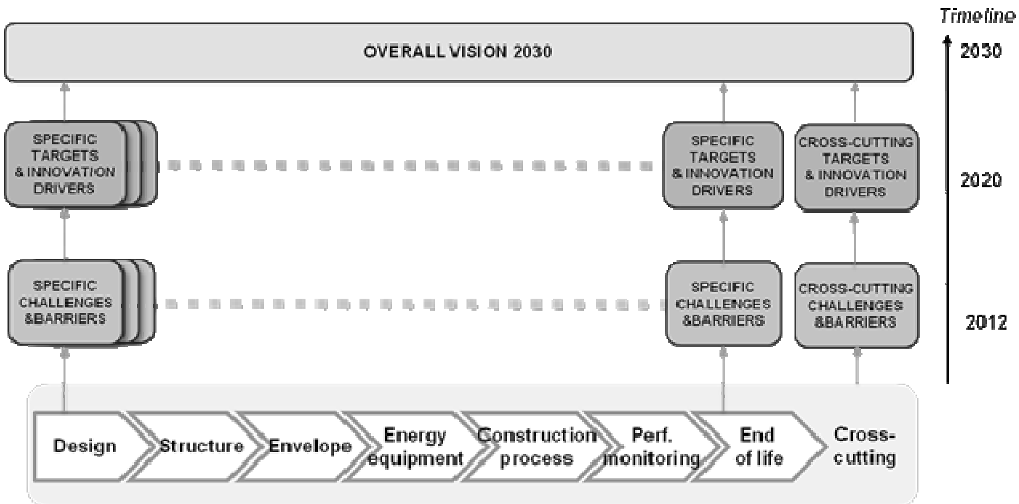

Figure 2: Representation of the segmentation of the value chain and road mapping process

This optimisation approach requires that all the stakeholders perform according to quality rules where interfaces and responsibilities between any of them are transparently exchanged. The innovation process will be open to various technologies, materials or processes focussing on valuable improvements. Interaction with other research areas especially the integration of supply systems for renewable energy including storage systems will be mandatory. Indeed novel Information and Communication Technologies (ICT) as well as materials technologies will be key enablers throughout the whole value chain, from the design phase to the end of life. An overview of the enabling role of ICT is provided in Figure 3.

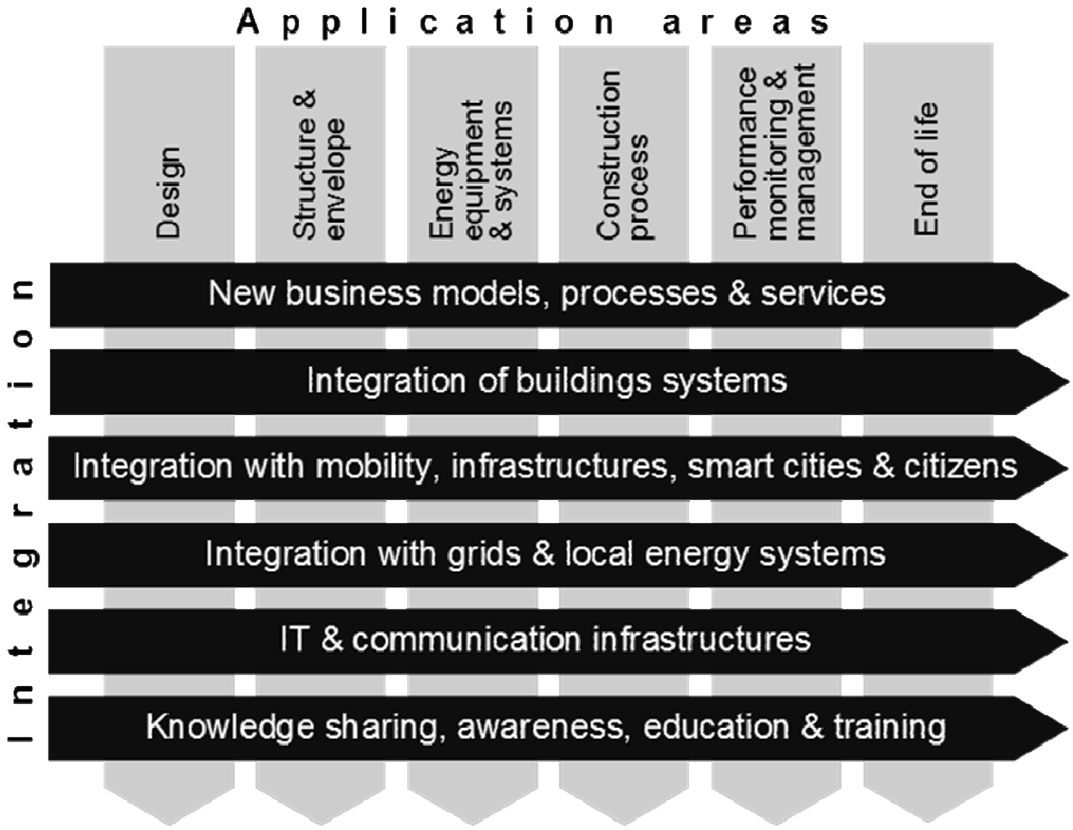

Figure 3: The pervasive role of ICT along the value chain

4.2 Main elements of the strategy

It is at the **design stage** that more than 80% of the building performance is set both in terms of energy savings (generation when embedded in a zero energy district) and cost of ownership over the life cycle before refurbishment. Yet, the relative gap between the design value for energy performance and the commissioning measured result is still too large (and will probably widen when the more stringent building code standards for 2020 are in place). A new regional and urban planning of smart grids and cities promotes decisions at the design phase for better solutions. Thus, planning with a holistic approach for energy-efficient and sustainable buildings (new and refurbished) will be mandatory. Hereby, ICT technologies from true interoperability to decision support systems can be used.

Load bearing structural parts of a building can be mechanically and thermally optimized with sophisticated tools: the focus must now be put on the embedded CO_2 which comes from the materials (concrete, various brickwork, steel, wood …). This CO_2 will become the most prominent part of GHG emissions as the share of energy neutral building grows. Alternative construction processes e.g. with significantly lower embodied energy will help to bind CO_2. Hereby, renewable energies and sustainable cultivation plays a key role.

The **building envelope** becomes the most critical part when it comes to energy efficient buildings:

- For new buildings, materials and energy equipment integration already allows reaching very low energy demand (e.g. based on a high heat resistance, high air tightness or integrated ventilation systems with connection to heat recovery systems). Yet, the investment costs have to be further reduced while taking care of several other design constraints (acoustics, fire, seismic, air quality, adaptation requirements for ageing population...). In the long run, active envelope could make buildings energy positive by, for instance, smartly managing solar fluxes onto the building.

- For refurbishment, the diversity of architectures and climates in Europe requires a whole value chain innovation process where design, technology choice and construction are even more intertwined than for new buildings – special efforts are likely to be necessary for cultural heritage buildings. The integration of the district dimension can allocate refurbishment performance settings to reach very ambitious zero energy districts. Overall, refurbishment depths must go beyond 70% while valuing non energy related benefits to make the business models more attractive.

- Prefabrication of envelope parts, multi-functionality and compact solutions presumably will significantly reduce costs and produce new markets.

The **energy equipment** must adapt to the new smart grids and to lower unit energy demands from more energy efficient buildings, which requires sizing down to-day portfolio while keeping energy efficiency at the highest level possible as well as unit investment cost down. Beyond existing technologies, breakthrough solutions can be expected from heating/cooling systems combined with renewable energy sources, storage (heat and electricity) and building or district integrated solutions in combination with smart grid technologies. Interoperable systems which integrate all different energy fluxes like electric energy sources and sinks, heat sources and sinks (including storage) and innovative control systems are required. The costs for different energy sources will vary depending on supply and demand. Smart solutions will offer best prices for investors and end-users.

Construction processes are now part of the critical path to reach the final energy performance: any defect can lead to disorders and even pathologies which hamper the durability of the building performance. Several complementary routes can be envisaged, with the envelope and the technical equipment at the heart of the integration process:

- Prefabrication of standard units which facilitate field integration.

- New field integration process with more detailed internal performance control following elementary construction steps. New sensors can help check intermediate performance steps before commissioning (ex: blower-door test in combination with thermal imaging for air tightness) which, in turn, require collective work in the field.

- Continuous improvement processes become part of a quality process which increases energy and comfort performances for new and refurbished buildings. RFID technology will improve productivity at the building site as well as the training of workers e.g. on the impacts of a wrong installation on the buildings' performance.

- Starting at the design phase new standardized BIM exchange formats allow a continuous information flow towards a computer aided construction process.

Performance monitoring (both at commissioning and during the building life) is mandatory: it enables smart grid integration, allows users to oversee and control their own consumption and allows detecting inappropriate operating conditions. Moreover, conditional maintenance approaches can bring added value in guaranteed performance contracts. New IT solutions and embedded sensors will come from other fields of use (transportation for instance) as pervasive technologies that will be user centric.

Performance management allows merging the best available technologies and processes to optimize both costs and performances of new or refurbished buildings. The ability to interact with smart grids will be mandatory. This implies not only connection capacities for energy supply including smart storage functionality, but also adaptable solutions for the buildings or districts themselves. The prediction of peak loads (e.g. by weather forecast) or support for low prices to load batteries for e-mobility will be implemented. Any changes of the boundary conditions in terms of changing energy production, energy demands, load cases, etc. will be handled. New learning control systems or control systems based on human behaviour may be introduced. Mitigation strategies for climate change can be part of this strategy. All these technologies are based on ICT.

End of life: building demolition is an environmental issue which will grow under the pressure of deeper refurbishment. It can be addressed, both at design (reusable components) and demolition levels (reusable materials). The building industry is already involved in significant waste recovery (with a focus on concrete, metal and plastics). Innovation is expected in view of contributing both to the lowering of embedded CO_2 and resource efficiency.

Some of the ICT have an even broader context for future new or refurbished buildings and districts:

- **Sensor networks** are key components not only as standalone devices, but also embedded in smart Energy Consuming and Producing Products [EupP] The vision of these devices includes growing embedded intelligence, for instance product and repair information.

- **User awareness**, occupancy modelling and decision support now become more complex in a scenario with variable prices for energy and changing supply and demand. Highly integrated solutions are planned at the design phase and influence even the buildings' end of life.

- **True interoperability** will reduce redundant information and information affected with errors. Beginning at the design phase all components of the value chain can be enhanced by secure and long-term working data models and interfaces.

- **New data support systems** provide reporting, data aggregation and statistical elaboration guidance and facilities (see www.concerto.eu). Regulation and standardisation e.g. for EPDs (Environmental Product Declarations) can benefit from it.

5. Conclusion

This new Research and Innovation Roadmap gives dedicated R&D trajectories for each element of the value chain of the building sector: progressive market availability of technologies and processes will come from large scale demonstrations. They will show irrefutably that the best technical and cost performances can be reached on time for the market demand, thanks to integration processes taking care of the global optimization at building or even district level, and data sharing to help minimizing the interface risks inherent to any such complex system optimization process.

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