This document was developed by ECTP’s (European Construction, built environment and energy efficient buildings Technology Platform) Energy Efficient Buildings Committee, in particular with the support of Olaf Adan (TNO), Germain Adell (Nobatek/INEF4), Ilari Aho (Uponor), Christian Artelt (HeidelbergCement), Antoine Aslanides (EDF), Maria Chiara Bignozzi (Università di Bologna), Javier Bonilla (Acciona), Raffaella Brumana (Politecnico di Milano), Ignacio Calvo (Acciona), Stefano Carosio (Università di Padova), Paul Cartuyvels (Bouygues), Marcin Cyhowski (UTRC), Emmanuel Forest (Bouygues), Ruth Kerrigan (IES), Kristina Mjörnell (RISE), Juan Perez (Tecnalia), Isabel Pinto-Seppa (VTT), Donato Zangani (RINA Consulting) and Alain Zarli (CSTB/ECTP).

Published in June 2018
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1 INTRODUCTION

The current EU RTD Framework Program, Horizon 2020, will run until the end of 2020. Discussions and preparations for the next Framework Program, Horizon Europe, that will cover the period 2021 – 2027 are beginning. This Position Paper has been developed with the purpose to provide insight into those current and upcoming buildings and construction-related key-challenges that we strongly believe deserve to be addressed within FP9.

As part of the European Construction, built environment and energy efficient building Technology Platform ECTP, it is the Energy Efficiency Buildings Committee’s goal to develop a common Vision and Strategic Research Agenda for all construction sector stakeholders. This common view will serve as a starting point for future R&D co-operations and networking that will develop solutions helping to overcome societal challenges and to ensure that the buildings and constructions sector, as a strategic sector in Europe, will, in the long term, secure its competitiveness and sustainability.


2 SCOPE AND APPROACH

Buildings account for 40% of total energy consumption and around 75% of them are energy inefficient. Low energy efficiency in buildings is due to a number of shortcomings, including lack of maintenance and insufficient investment, defective construction (either for inappropriate choice of materials or lack of professional expertise), change of use, outdatedness of the building, and others. Europe’s energy inefficient building stock is huge and, with the current rate of renovation of around 1% of buildings each year, it would take a century to upgrade the building stock to modern, near-zero energy levels.

There is a crucial need of innovation to improve the situation and deploy energy-efficient and low-carbon solutions in the built environment, to avoid an ever-increasing inefficient buildings stock in the next decades. According to a new report by the EU-funded iBRoad project – The Concept of the Individual Building Renovation Roadmap –97% of the EU’s building stock, amounting to over 30 billion m2, is not considered energy efficient, and 75 to 85 % of it will still be in use in 2050. The ambition of ECTP is to reach at mid-term a 4-5% renovation rate in Europe by 2027 (with +0.5% each year), in order to cope with the evident need to achieve rapid growth in replacing particularly inefficient and carbon-intensive buildings through developing appropriate innovation partnerships and business models.

Clean energy buildings are about much more than saving energy: they are built with enhanced materials with increased durability and reusability, increase occupant comfort, quality of life and productivity, have the potential to integrate renewables, storage and digital technologies and to link buildings with their surroundings, especially the transport system. Investment in a clean energy building stock can drive the transition to a low-carbon economy. With all the know-how gathered in technology innovation in buildings in the framework of the EeB PPP in H2020, the E2B Committee sees the need to extend from Energy-efficient to Resource-Efficient Buildings on one side, and from buildings towards Energy-efficient districts and ultimately Carbon Neutral Cities on the other side, enabling the technology developments that are needed to face Europe’s challenges and ambition by 2030 and 2050.

EU’s Accelerating clean energy in buildings report also recognizes the need for expanding our scope by stating that “the EU is already a global leader in innovation systems for buildings. Integrating energy efficiency, renewables, storage and connecting to digital and transport systems through buildings allows further expanding on this leadership and making the most of the favorable regulatory framework”.

This will also support the technological developments that are needed, as defined in the Clean Energy for All Europeans Package. In particular, the value proposal of the E2B Committee targets several of the gears that need to be empowered to achieve a modernization of the European Economy: Innovation, the Energy Union and Climate Change, the Circular Economy and the Digital Single Market.

Innovation, by defining the technologies that need to be developed, from research to market uptake, aiming for a modernization of the construction sector and its contribution to the European economy and welfare, and creating synergies between the energy, transport, circular economy and digital market.

The Energy Union and Climate Change, with a focus in the technology requirements to reach a renovation rate of 4-5% by 2030 while generalizing the concept of low-carbon (near zero) energy buildings.
The Circular Economy, with the built environment and construction sector having a pivotal role to reach the targets set in the Circular Economy Package, by fostering the generation of new circular economy models based on the valorisation of waste streams from industrial sectors for construction purposes, through the establishment of industrial symbiosis relationships at regional level.

The Digital Single Market, by the development and integration of digital technologies to increase the efficiency of the construction processes and infrastructure operation, as well as facilitating the adoption of a digital public procurement process.

While the need for innovation at building scale and investing in buildings remain, ECTP has revisited its strategy: reaching the sectorial goals, as well as the energy goals, requires to step-up and focus the effort beyond the building scale.

Hence, ECTP’s proposal for the next FP9 is to enlarge the scope of RDI activities and to move from (passive) Energy Efficient Buildings to (active) Low-Carbon Built Environments, i.e. extending the considered dimension from buildings to blocks of buildings and districts, and embracing the larger Built environment as an enabler for innovation integration (e.g. recyclable, bio-based materials, intelligent and digital technologies, smart grids for optimized interaction with the environment, circular economy models…) for enhanced sustainability in districts and cities.

The ECTP post-H2020 evolution can be synthesized as shown in the following figure:

The following research priorities summarize the key technology challenges arising from the extended scope described above. The E2B Committee is proposing to tackle and broke down these challenges into specific research priorities in the frame of HORIZON Europe:

❖ Buildings and block of buildings, including retrofitting uptake: to increase the retrofitting market uptake.
❖ **Active Utility Nodes**: to integrate renewables and storage and facilitate more active customer (prosumer) engagement.

❖ **Digital transformation**: to seamlessly collect data from new and existing buildings on IoT and cloud based platforms to which stakeholders of the value chain have access facilitating design processes, renovation and operation & maintenance issues;

❖ **Performance optimization through monitoring and intelligent management platforms**: to effectively measure the impact achieved and to trigger the replication potential of innovations developed;

❖ **Interfacing with the built environment**: to link buildings with the surrounding transport system (including multi-modal transport hubs and transport infrastructures), future smart energy grids (including thermal and electrical energy networks), as well as to fully integrate the circular economy principles in the built environment and the construction sector;

❖ **Integration and cross-cutting issues**: to ensure stakeholders’ engagement, users’ awareness on energy efficiency, new business models and financial schemes, systemizing integration and market uptake.

These challenges also contribute to the UN Sustainable Development Goals\(^1\), directly or indirectly tackling several of those:

- Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable
- Goal 12: Ensure sustainable consumption and production patterns
- Goal 13: Take urgent action to combat climate change and its impacts

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\(^1\) [https://www.un.org/sustainabledevelopment/sustainable-development-goals/]
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3 PRIORITY TOPICS FP9 2021-2027

3.1 New and Retrofitted Buildings and Blocks of Buildings (Communities)

In the vision for the city of tomorrow, buildings cannot be isolated units anymore but they need to increase their active role. For both new neighbourhoods as well as retrofitted ones, optimisation of resources goes through exchanges of power, fluids and data from one building to another. Mixing functionalities of these buildings contributing to this optimisation will also require flexibility in the solutions applied to each specific demand. Finally, exploitation of the results of the past and ongoing projects should form an essential part of the roadmap 2021-2027.

Continuing the work of the PPP on materials, components, single buildings, building blocks and neighbourhoods will have to be deeply rooted in the new challenges that have emerged in those past years: life cycle approach, circular economy principles, digitalization of the construction sector, sustainable and smart urban development, and integration to smart energy networks including storage systems. Although some of these were touched upon in a number of past projects, they now have to represent the backbone of a more global and integrated approach.

Another important element to recall from the PPP’s deliverables is the work on the geo-clustering of solutions, an essential approach on a rather diversified continent.

In addition to energy efficiency, a building must ensure a high quality of living. In this frame, person, environment and building are strictly connected reality, the new challenge is their interaction to enhance sustainability and healthiness from personal spaces (modern homes) to common spaces (i.e., commercial buildings).

The chapters proposed to cover the «Building Blocks New and Retrofitted» section have been chosen trying to limit overlap with other proposed sections. Proposing successful solutions will often require combined actions of these sections.

3.1.1 New Buildings and Blocks of Buildings

Key priorities for this topic are aimed to be applied either at single building scale but considering the building as a unit of the district, or providing a solution to be implemented in the block of buildings as a unit itself:

- Design solutions based on bioclimatic architecture and nature-based solutions (biomimicry, i.e. copying solutions found in nature, or rediscovering vernacular architecture) and nature-based solutions (i.e. solutions available in nature, such as those using plants and even animals to address a challenge with a positive impact to the environment), and solutions based on designs that are modular, adaptable and re-sizable.
- Advanced multifunctional materials and components, with enhanced performance and durability, which can combine energy characteristics with optimal re-using/recycling potential.
- Lightweight construction approaches, providing benefits in terms of demand for heavy duty equipment during construction or assembly as well as in terms of safety against seismic actions, and other structural threats, including textile architecture and use of bio-based composites.
• Development and integration of construction processes based on mass-customization of the production processes, quicker, safer, and providing higher overall quality standards to the citizen.
• Smart energy supply and storage systems for electrical power interconnected with the grid due to more and more fluctuating renewable energy.
• Intelligent and efficient heating, ventilation and air conditioning (HVAC) systems fully integrated with renewables and storage that provide multi-comfort benefits to the occupants.
• Integrated Design solutions, through storage end exchange to improve performances of energy to even out demand indoor environmental quality: air quality, hygiene and supply and heat and power between buildings cleanliness, acoustic comfort.
• Solutions for integrating Buildings and its users as a combined unity (energy prosumers) in the block/neighbourhood Virtual Power Plant (section 3.2).

3.1.2 Retrofitting technologies for an enhanced renovation rate in Europe

It’s widely known and acknowledged that in Europe, while new buildings can be constructed with high performance levels, it’s on existing buildings, being predominantly of low energy performance and subsequently in need of refurbishment works, where the energy efficiency measures must be concentrated.

Especially for large building owners, the technical capacity to operate deep energy renovation programs at a faster rate and larger scale has been demonstrated but some barriers limiting its global application still exist, such as stakeholder’s restraints due to lack of involvement and too long onsite renovation times, poor reliance on technologies, and ROI conditions incompatible with financing capabilities leading to increasing rents for tenants and higher living cost for residents. Indeed, initial cost is often the main barrier that hinders market uptake, so a further effort is needed to both reduce them by introducing different forms of pre-fabrication (thus reducing both on-site which is expensive and disturbing works) and improve the whole process by an integrated approach of technology solutions and consider life-cycle costs.

As an example, the European collective housing sector has become more and more aware of the energy efficiency challenge and the regulation evolution (from EPBD to NZEB and Positive Energy buildings, including the new 2030 EU policy targets), and they are willing to renovate at higher standards, but not paying the premium price. Building owners are actually asking for more cost-effective ways of achieving deep renovation because they need to apply them now. With better, faster and cheaper solutions they could both increase the rate and achieve greater savings.

To achieve this we need to develop, set up and test a conceptual framework to radically change design and procurement processes to optimize every aspect of a construction or retrofitting operation: participation and engagement of stakeholders including residents sharing the right information at every stage is key and allows to shorten time, to reduce waste, to improve quality and to lower costs. For instance, applied to energy efficiency, results of new procurement and organizational processes already documented like IDDS or Lean management can make a difference if combined with innovative building technologies for envelope retrofitting and high-performance installations working together in combined systems. Indeed, mature technology systems for production and storage of renewable energy need to combine their action in complementary installations to do a performance jump that will lower life-cycle costs as well as environmental impact.
Renovation is one of the biggest challenges for the construction sector related to energy efficiency and it is a bottom-up one: end-users on the field do want and are asking for cost-effective and high-performance solutions targeting NZEB or Positive Energy performance of building renovation to be developed and applied allowing to target deep renovation works. To address this challenge we need to define priorities to be applied at single building scale but considering the building as an unit of the district:

a) To develop, deploy and promote fully operational digital Backboned management processes aiming at the fulfilment of the whole lifecycle in the renovation processes in order to reduce time and costs.

b) To enhance the market uptake of energy efficient renovation (including deep retrofitting of buildings) aiming for a multiplicative effect in Europe that will increase the actual existing renovation rate, by overcoming the technical and societal barriers still existing in order to be able to reduce the “energy performance gap”, guarantee performance in operation (including addressing user behaviour) and therefore preparing the uptake of Energy Performance Contracting, which represents a yet largely untapped fertile market for EE/RE technology and energy providers, such as manufacturers and ESCOS.

c) To dramatically reduce construction times on the building site by promoting and applying Lean Management tools and implementing off-site construction, and building extensions reducing installation time by at least 30% compared to typical renovation process, which should return in substantial economies and less disturbance for building residents.

d) Related to the former, to fully promote development and implementation of modular off-site construction and building extensions. This is not only to consider massive industrial prefabrication, but also full off-site construction of integrated systems and components, that can be then fitted on-site in less time and with less errors.

e) Adoption of solutions based on buildings extensions which represent a fast and efficient solution for improving the overall building energy efficiency and, increase the ROI when included in building renovation.

f) New simulation software and approaches for energy performance contracting for renovation, enabled by dynamic models.

g) To provide the development of the full range of skills that is required to manage sustainable, energy-effective retrofitting projects by the contractors (from a cost-effective point of view), and appropriate exploitation and maintenance by building owners / facilities managers in an sustainable affordable way (in terms of Life Cycle costs), life cycle GHG emissions (embodied energy for materials as well as for operation) and social aspects – so as to generalise the implementation of a global, effective, energy-efficient retrofitting strategy for the stock of existing buildings in Europe – targeting NZEB or Positive Energy level.

h) To consequently allow the advent of a new generation of skilled workers and SME contractors in the construction sector aware of the need of a systemic approach towards energy efficiency in retrofitting, and with a capacity to perform onsite implementation of technologies twice as quick, while enhancing the overall quality.

i) To innovate in organizational aspects, in construction processes and in procurement procedures, even questioning the actual business as usual organization of tenders and the regulatory framework (e.g. Integrated Design and Delivery Solutions, although promising, are hard to implement due to legal constraints, notably concerning public tenders).
j) to integrate user behaviour and enable participatory approaches from the design phase and all over the life cycle of the works, commissioning and operation to ensure user acceptance and engagement.

3.2 Active utility nodes

Buildings are becoming more and more active, participating to the management of utilities, as well as enabling synergies between them. We shall thus designate buildings as no more “passive objects in which water, energy and air is used”, but parts of infrastructure which offers not only delivery points of utilities, but also utilities generation capacities, together with the necessary intelligence and control features to act as local optimization point.

Buildings are built to fulfil specific needs of inhabitants or users. Growing capabilities in forecasting and anticipating demand allow to manage utilities more smartly, avoiding for example oversizing the delivery system for utilities by considering it should be able to deliver a peak demand each and every moment in time.

Buildings’ utilities (electricity, gas, heat, cooling, water...) are not all required at the same time or in the same quantities, even between the different levels of a single building. Moving beyond “mono-utility” optimization, future buildings will be integrated in a system, taking benefit of potential synergies between utilities and buildings’ supply and demand to reach a global optimum being smarter than the addition of mono-utilities optima. The ability of delivering flexibility and hence supporting the utilities will allow buildings to actively participate to the Single-Digital Market and be rewarded for the impact and quality of the services delivered.

By transforming buildings into active utility nodes, each future building can be considered as a “node” of an overall network, contributing to an overall balance of the networks while having the capability to interact with other nodes and cooperate so as to deliver the required service. In order to achieve this, the following technological challenges must be met:

- Development of intelligent systems being able to maximize the efficiency of utility systems in infrastructure, turning them into active components. Smart management, which includes forecasting capabilities as well as storage, exchanging of heat and power, should greatly reduce the cost of infrastructure which today do not embark dynamic adaptive and automatic learning capabilities.
- Development of integration synergies between different utility systems, including the development of storage systems, to foster a global smart energy system.
- Development of the required capabilities (decentralized and distributed resources, increased ICT capabilities, business models) to shift from a highly centralized management of networks to a more distributed and cooperative management system, favouring local actions to be implemented.
- Development of standardized management, communications and integration technologies in order to guarantee interoperability of the adopted solutions.

3.3 Digital Transition

Digital technologies have an increasing impact on the construction sector and quality of living conditions. These technologies are already changing the way buildings and cities are planned, designed, constructed,
operated and maintained. They also allow the built environment to be used more efficiently for the benefit of European citizens.

During the last decade, with the valuable support of the cPPP EeB, the construction sector has been developing a technological transformation that has contributed to the successful digitalization of its processes (CAD/CAE tools, facility management tools, visualization tools, autonomous and self-aware platforms for buildings and districts...), but mainly one by one, spreading in technology and stakeholders. The digitalization of the construction processes and the successful evolution toward the Future Internet as basic communication infrastructure of the European society are creating the required framework to jump to a new stage in the holistic and seamless digitalization of the construction sector, since the initial design stages to the operation and maintenance of the built environment.

3.3.1 Value chain integration, including end-users

The poor integration of the different stakeholders in the construction sector value chain is one of the reasons of reduce performance in terms of time to delivery, overall costs, innovation delivered and end-users satisfaction. The adoption of a “Virtual first” strategy (e.g. instead of drawings and/or real constructed buildings analyse virtual buildings by means of simulations and virtual reality) would allow an iterative and collaborative process among the different stakeholders and anticipate and avoid the different problems and poor performances that would appear during construction, operation and maintenance stages.

The lack of previous projects knowledge, in particular impact created, is another factor that reduce the performance of new and renovated buildings. Usually, when a building is delivered to the owner, the design and construction teams are not anymore responsible for the operation and maintenance of the building and thus they do not receive any feedback about the real performance and impact of their design decisions and their construction works. Consequently, similar decisions and mistakes are repeated for new projects. At the same time, it is very difficult benchmarking the performances of a building in relation to other similar buildings and learning what are the best practices.

The digitalization of the construction and operation of the built environment will make it easier sharing information about the real building performances and compare them with the expected in the project design.

In the same way, the adoption of an standardized open BIM as the reference framework to manage all the information about the built environment (model + real time data) will make it possible to compare the performances of the building stock of a company, city, region... in order to analyse weaknesses and strengths of the buildings, define action plans to improve the performance of the one with poorer performances and identifying best practices in design, construction, operation and maintenance of the built environment.

Key R&D challenges in this topic are:

- Development of a minimum set of information needed to create BIM of existing building in order to create a set of basic information to define renovation projects and keep track of such interventions.
- Development of Open BIM (Building Information Modelling) as the reference framework to support and make the interaction among the different stakeholders more dynamic and provide the necessary interoperability among the different ICT tools that are used by each one.
- Integration of cloud technologies as the infrastructure to provide a collaborative environment among the construction sector stakeholders.
- Advances of digital security (blockchain...) to overcome some of the barriers related with the reliability and responsibility of digital information (author, authenticity...).
- Development of smart application able to support the operative phases on construction site.


### 3.3.2 Smart operation and maintenance

There is an increasing social demand of more sustainable, efficient, healthy and comfortable built environment. To satisfy these demands the old paradigm of a "static built environment" is no longer valid. Tackling these demands requires an “adaptable built environment”, which is able to automatically learn its context (user activities, weather conditions, available renewable energy sources (RES), energy grid restrictions...) and adapting and responding to it (controlling thermal flows through the building envelope, facilitating demand response, changing operation set-points...). The continuous and fast development of the IoT technologies (wireless communication, energy harvesting for sensors...) are making feasible and affordable the collection of the data that are needed to represent the built environment operations conditions and its context without limitations about how many data are needed, where data is collected, pulling rates, autonomy of the sensors... However, the impact is not only in the collection of data but also in the value extracted from (big) data. Nowadays, several technologies are available to analyse data, some based on computer simulations of physical processes and others based on data analytics, machine learning and artificial intelligence for big data. Furthermore, supported by standardization, IoT and intelligent technologies will support cost-effective installation and commissioning of the different building systems streamlining and automating the labour-intensive manual tasks that are often poorly performed or neglected resulting in a significant gap between the actual and design building performance. Such technologies will also ensure the building performance is maintained throughout the life cycle through continuous commissioning.
Same concepts and technologies can be applied to effective maintenance of the built environment. Current strategies are based on preventive maintenance (system components are maintained when a predefined operation time is reached), or “run to fail” strategies, (system components are repaired when they fail). First approach usually implies high cost and the second one usually reduces the quality of the services. At the same time, none of these strategies is able of preventing unexpected failures and unforeseen costs. Current ICT for data collection and analysis make it possible optimizing the maintenance strategies, predicting when the intervention is necessary to recover the expected performance of the system (e.g. cleaning a filter) or avoiding its failure (e.g. replacement of a key component).

Key R&D challenges for the development of smart operations and maintenance are:

- **IoB – Internet of Buildings**: Integration of relevant technologies (Big Data, IoT, cloud and edge computing, artificial intelligence) in the blocks of buildings that facilitate intelligent and proactive building operations, optimization of maintenance / continuous commissioning strategies by targeting accurate predictive maintenance scenarios and the exchange of information between the blocks of buildings and the rest of components in the ecosystem.

- Integration of real time data with the BIM will also create more friendly and accurate monitoring and control systems. For example, virtual reality and augmented reality techniques could be applied to provide information to building users or to guide the maintenance crews in their tasks. This approach would also make easier the integration of the control system with the most powerful simulation tools.

3.4 **Performance monitoring, diagnostic and optimisation**

Performance monitoring and management are fundamental requirements for future smart grid/cities technologies. Measuring and data collection should be inherently part of building and districts energy acoustic, lighting and environmental performance monitoring and forms the foundation for management technologies.

The desired features of effective performance monitoring and management can be summarized as follows:
• Energy performance is monitored continuously at the building and wider district levels over long time periods, combined with safety, security, comfort and any other monitoring system

• The building and district energy performance is constantly optimised to meet performance criteria and evolving user’s requirement and behaviour (including load forecast and flexibility to energy grids)

• Energy performance monitoring assimilates three phases coherently i.e. pre-retrofitting, commissioning and retrofitted phases, each of them having tailored tools and requirements

• Reduce the excess of unused, difficult to understand and not accessible information and data on real energy performance of buildings

• 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

The main barriers preventing wide replicability of innovative performance monitoring and management solutions are described below.

Technical / Technological:
• Lack of low cost, low maintenance and reliable sensors and systems
• The connection to greater units at district or city level does not exist yet
• Energy performance monitoring systems with advanced functionalities are not yet available
• Energy equipment is insufficiently interoperable
• Operations are not flexible enough as baselines are very conservative
• A unified standard on parameters needed for monitoring is lacking.

Economic:
• Lack of low-cost innovative energy performance monitoring equipment.

Societal:
• Public acceptance and awareness of performance monitoring is lacking
• The use value and behaviour of end-users is poorly understood
• Energy performance need to cope with other monitoring and management aspects, including those related to buildings of cultural value.

Regulatory:
• Legislation to frame appropriate energy metering in buildings is needed
• European legislation on energy management and trading at district level is needed
• Unified procedures and protocols to safeguard the balance between privacy and accessibility of information are lacking.
Generally, three principal phases are distinguished with respect to Performance Monitoring, each of them with tailored requirements, i.e. the pre-retrofitting, commissioning and retrofitted phase. A solid and sound performance monitoring approach basically should address all three coherently. Key in our approach is to have a unified monitoring approach that is fully transparent to all stakeholders involved, including the end-user. This is a primary requirement for successful and large-scale implementation of energy performance contracts.

Three main targets are identified as key to advance towards the overall challenge described...

### 3.4.1 Support to performance contracts uptake

This includes two key focus points:

1. **Common indicators, metering technologies and data analysis methods to measure and investigate building performance and flexibility at pre-retrofitting, commissioning and beyond (service life after retrofitting), operation and management.**

   Such guidelines are required at European level to promote guaranteed performance contracts in view of securing pathways towards sustainable building decarbonisation and enhanced well-being by 2050. This European wide approach must go beyond the IPMVP methodology which is very US centric and proved to be ineffective in certain applications.

2. **Optimised integration of energy performance metering and analysis with the other performance systems (safety, security, comfort, etc.) to enable performance-based contracts.**

   The integration of all existing monitoring systems reduces costs and increases the synergies among all systems, allowing a more reliable and robust system. By considering the inhabitants/residents in the monitoring of the building, a major key factor influencing the overall energy performance of the building, performance-based contracts reduce risks and facilitate implementation. The following research and innovation priorities are identified:

   - Simple, easy to implement and robust monitoring methodologies for long term monitoring. This includes minimal cost sensor configurations and smart algorithms for (big) data assessment (e.g. using BIM data as a reference), data-error identification and repair of sensing and monitoring devices. Guaranteed full transparency in procedures to assess performance, as a primary requirement for implementation in energy performance contracts. Standardized third party monitoring enhances transparency and impact assessment.
   - Development of performance indicators at European level allowing comparisons between regulations, user/client requirements and targets, design models and real-life data, including end user behavior and end-user perception (indoor environment including air quality, ventilation, lighting, etc.);
   - Development of performance indicators at European level allowing comparisons among regulations, design models and real-life data for district energy efficiency performance.
   - Definition of procedures and protocols to enhance cyber security and hence to safe-guard privacy of tenants, building-owners and office-workers, but simultaneously securing accessibility of information (on a need to know basis) with sufficient level of details.
   - Tools and methodologies for quick and robust screening of building and energy systems performance and flexibility, using limited, short term quantitative data on use and performance.
This also implies the development of model-based, smart algorithms using BIM data and a big-data base as a point of reference.

- Specifically: Efficient and practical means of measuring and monitoring the IEQ (Indoor Environment Quality, including IAQ, thermal comfort, noise, light environment, moisture, radon...)

### 3.4.2 Conditional maintenance

Condition-based maintenance requires extensive instrumentation of energy equipment\(^2\), and data processing tools at BEMS level to produce real-time diagnosis of building working conditions and energy performances. It would become part of performance guarantee contracts, which may be also envisaged at district level for cooperative buildings. Strategies and business models for efficient and cost-effective maintenance, such as performance-driven condition-based maintenance, need to be developed and implemented, taking into consideration the scaling-up and replication issues brought by national regulatory schemes.

The following research and innovation **priority** is identified:

- Development of self-diagnosis subsystems (sensors and algorithms) leading to conditional maintenance improvement, based on LCC optimisation of subsystems (energy equipment, envelope) or systems;

### 3.4.3 An EU-wide open database on energy performance

A European approach is implemented to measure, monitor and compare the energy performance of buildings and use values of energy efficient buildings in Europe, fully adopting the EU principles of Open Access and Open Data.

**Justification:**

- Knowledge on the building stock and its dynamics (i.e. medium-long trends in new construction, renovation and demolition activities) constitutes the scientific background for effective policy making and allowing monitoring the progress of such policies and addressing adjustments where necessary.
- This knowledge base serves as a point of reference for crosschecking results from building simulation tools, and as calibration/performance objective for future real constructions.

Based on best practices and repositories available, a European observatory\(^3\) would monitor energy performance to create a European wide database of real life results on new and refurbished buildings, tracking progress towards the achievement of 2020 and 2050 targets. This observatory keeps an updated track record database, including accurate and useful building specifications in order to establish a knowledge base that would record and centralize energy performance data and global cost data of exemplary buildings that are representative of larger segments of the stock. Each record would include comprehensive information about the building specifications and usage.

The following research and innovation **priorities** are identified:

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\(^2\) Conditional maintenance also calls for improved defect forecasting/diagnosis using fault detection sensors

\(^3\) A similar approach is used by the DoE in the USA, which yearly publishes an annual building book, next to best practices which implies that the proposed approach makes use of modern communication technologies.
• Development of an OPEN, i.e. public accessible, database collecting R&D, energy, performance data from demonstrations and real-life results
• Development of a European standard that defines the parameters for energy performance monitoring e.g. including frequency of data collection, notification, parameters for an API to communicate between different monitoring-sets, terms of reference for supporting software tools.
• Development of standard protocols for “in vitro” and “in vivo” use-value measurements of energy performance
• Creation of a European network of use-value measurement laboratories.
3.5 Interfacing Low Carbon Buildings with the built environment

Buildings are not isolated elements in the built environment ecosystem; on the contrary, to achieve a low carbon footprint built environment, the interfaces between buildings and their surrounding built environment must be fully considered.

3.5.1 New approaches to circular economy and nature based solutions at district level

The circular economy moves away from a linear approach of consumption (make-use-dispose) to an ecosystem where materials, products and components are held in repetitive loops, maintaining them at their highest possible intrinsic value. The benefits that come from following the principle of circular economies can be substantial. According to the research documented in “Finding growth within: A new framework for Europe,” a circular economy could generate a net economic gain of €1.8 trillion per year by 2030. The building sector, for example, could reduce construction costs with industrial and modular processes by half compared with traditional on-site construction.

Nature-based solutions have gained momentum as a valuable alternative for the restoration of ecosystems and increase resilience of the built environment. This includes the development of green infrastructure to tackle challenges such as pollution or temperature events, etc. It can be shown that a combination of open spaces, parks, nature areas and buildings with green roofs and facades interconnected can reduce peak temperatures by up to 4.5°C4.

Key R&D topics in this area are:

- Development of solutions for recycling building materials into a new generation of the same material without loss of functionality (as opposed to traditional processes)
- Design for longevity, adaptability and disassembly
- Development of integrated circular city design approach
- Development of nature-based design solutions based on low impact materials with intrinsic recyclability properties for their application in the buildings and the built environment flexible, durable, reused and reusable parts as components for building construction, including the uptake of sustainable biomaterials.
- Regulation, standardisation and business models creating conditions for a functioning market for reuse and recycled materials

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4 The Circular Economy in the Built Environment; ARUP (2016)
3.5.2 Multi-modal transport hubs and urban mobility infrastructures

Transport hubs are extremely important because the increasing flow of passengers and goods has to be managed within and between urban centres. As nodes, hubs must intelligently network various transportation systems so that people and goods can be transported in a safe, efficient, and environmentally sound manner. Given their visibility and nature, buildings, neighbourhoods at major transport interchanges also have the opportunity to engage a vast number of citizens. Interchanges can set new standards in the use of building materials, renewable energy sources and smart integration of digital travel applications.

In the future, an interchange should take up the role of the energy producer, not only of an energy user. Interchange installations offer options for rapid and slow charging of other electric vehicles such as electric buses or (shared) e-cars, e-bikes, e-taxis. Moreover, the design of a new interchange must maximize on-site energy generation, local source materials and use alternative energy sources where possible.

Key R&D topics in this area are:

- Open data hubs based on multimodal transportation infrastructure for providing more reliable transportation services
- Technology processes for the development of multimodal transport hubs that create minimum interference with the built environment, integrating the development of new materials and digital technologies
- Developing of infrastructure solutions to support the integration of automated driving into the built environment.
3.6 Integration and cross-cutting issues

3.6.1 Citizens engagement

The built environment of the future will be smart and interconnected. To take full advantage of the smartness of the city and of the interconnected infrastructures also citizens need to be "smart" i.e. connected with their environment and able to interact with it, and able to embrace smart and green solutions in the daily living schedule making "smart" lifestyle choices. The consolidation of citizen awareness and willingness to implement smart and efficient behaviours will be a driver to get conscious engagement.

Suggested Priorities:

- Definition of policies in collaboration with local authorities promoting engagement of citizens and foreseeing rewarding for active participation and stimulating adoption of energy efficiency behaviour.
- Networking, sharing best practices and promoting harmonized methodologies and standardisation of protocols: there is a need on high quality standards for the regulation of solutions both in terms of services and products dedicated to the engagement of users and their interaction with the system.
- Promoting education and training activities between industry, academia and final end users including consumers; consumers need to be properly informed about the possibilities offered
by the interaction with the system and trained in the use of the new tools for instance using smart games.

- Digital management of buildings through **smart** mobile applications, available to all without the need to expensive and dedicated hardware solutions.

- Support and incentives for smart communities where citizens co-invest in new technologies together with local authorities and utilities, e.g. using crowdfunding mechanisms to install renewables or storage systems or retrofit part of the city in order to reduce costs and improve quality of life.

- Promote transparent mechanisms by creating a more secure eco-system where the citizens can not only understand but promote themselves new technologies and solutions.

- Inclusive design practices to enhance citizen engagement

- Circular design practices to enhance citizen engagement

3.6.2 Business and financial models

New business models should be developed to address fragmentation of the European building sector that is not yet able to offer holistic solutions for deep renovation at acceptable cost and quality. Renovation processes are seen as costly, time-expensive, disruptive and risky by the consumers. Innovative business models which allow consumers and the market to invest with confidence in long term operation, maintenance, reliability and service levels therefore need to be developed.

Most of the required solutions and economic and technical data exist, but need to be collated in a harmonised way, organised, synthesised and ‘packaged’ so as to select, fine-tune and validate the most promising ones and accelerate their acceptance by the market players and consumers. The main task is therefore to implement a holistic approach over the whole value chain to define, enhance and replicate integrated refurbishment packages.

**Suggested Priorities:**

- Development of **collaborative platforms** to facilitate exchange of information among involved stakeholders promoting innovative business models resulting in optimised design and cost reduction.

- Identification of new business models based on refurbishment packages applicable to different contexts increasing the EU renovation rate

- Definition of policies encouraging circular economy approaches, for instance promoting a second life to technological devices still operational but overcome by the new models such as tablets, smartphones or sensors that can be reused where the application of technologies less performing may be envisaged. This would offer the possibility to all citizens, including those with limited economic possibilities, to be engaged, at the same time contribution to the reuse of electrical devices that otherwise would become waste.

- Pooling energy consumption and production, using Blockchain (e.g. Certification of solar energy origin). Blockchains are gaining attention as a new platform technology driven by transaction history information for financial transactions, offering the benefits of lower intermediation
costs with more transaction impartiality and transparency. Their use as a financial transaction platform has the possibility not only to bring about changes in the business models of existing financial services, but also to create new financial services and businesses.

- **Novel financing instruments**: the development of advanced solutions for energy efficiency and storage capacities in buildings and their application requires a strong financing base that is difficult to access for start-ups. Policy makers could ensure the set-up of public financial solutions such as tailored public procurement mechanisms (big tenders split into smaller lots), and loan guarantees to support the research, development, prototyping and innovation in this sector. Changing energy prices due to an oversupply or undersupply of renewables can lead to urgently needed storage capacities with new business models. The expected load removal in the grid will help to increase both the technical efficiency factor of renewables and the overall cost efficiency.

- New rewarding mechanisms for those buildings providing additional services and flexibility to transport systems, digitalized utilities and smart cities.

### 3.6.3 Systemising integration and uptake of sustainable innovation

Systemizing Integration and replication procedure need to be supported by policies to simplify processes and avoid the legislative segmentation.

**Suggested Priorities:**

- Definition of mechanisms to be able to replicate real success stories across Europe. Definition of a **label systems for sustainable innovation** that has provided certified results allowing the possibility to replicate virtuoso achievements

- **Certification**: Today, “green” labels are more and more co-opted by industry for marketing purposes. As a consequence, customers are becoming confused and even sceptical about the real sustainability of the products and are demanding more relevant information about the products they buy. In the building industry, consumers are demanding more transparency from suppliers. Renowned certification of products, professional construction services and key processes could become a driver for growth and increased internationalization of the sector, in particular for SMEs of the value chain. Indeed, officially certified product may be seen as a real guarantee of quality by the customer. A certification of buildings materials, components, building technologies may be an efficient mean to make the client trustier to buy and to use the product, and to strengthen the brand on international markets.

- **Standardisation**: Policy action should be taken to accelerate the standardisation process at EU level in order to decrease the administrative burden, to reduce the time and costs for applications for business licences and permits, and thereby to facilitate the development and the export of advanced solutions. Besides, standardisation and certification at EU level of advanced building components and related services, including energy efficiency solutions, could considerably support companies for entering the international market and thereby getting more visibility

- **Intellectual property** remains a complex and costly process for advanced building and construction solutions, in particular for SMEs, above all if companies intend to get their technologies protected across several EU countries. Still, the system and procedures are different from
country to country. Policy makers should ensure to provide support to companies by strengthening the existing IPR support mechanisms (e.g. through Technology Transfer Organisations), reviewing and simplifying administrative procedures and establishing one stop-shops providing services for companies, especially for IP matters, and introduce tax incentives on intellectual property protection.
4 IMPLEMENTATION

The development of the research priorities that have been along this document serve the purpose to establish an initial point of discussion for their future deployment in Horizon Europe Programme, and their Prioritization and Implementation shall be further detailed in discussion with the European Commission.

First and foremost, these priorities will feed the ECTP proposition for Horizon Europe Programme, as a continuation of the H2020 EeB PPP. Energy and Buildings are key priorities in the overall ECTP proposal, and these priorities shall become part of the Roadmap for the next Framework Programme. As it has been mentioned, the ECTP proposal will extend their scope; as such, some of these priorities might not fall fully under the new proposal, but they shall still be considered under the overall umbrella of the Horizon Europe Programme by the European Commission and incorporate these priorities through the different instruments that will be part of Horizon Europe (i.e., in analogy to H2020, some of these priorities not included in the EeB cPPP could be considered as topics in the Energy or Climate Societal Challenges work programmes).