ENERGY EFFICIENT BUILDINGS
AN ECTP COMMITTEE FOR INNOVATIVE BUILT ENVIRONMENT

ECTP Energy Efficient Buildings Committee

Horizon Europe 2022-2027 POSITION PAPER

ECTP
INNOVATIVE BUILT ENVIRONMENT

This document was developed by ECTP's (The European Construction, built environment and energy efficient building Technology Platform) Energy Efficient Buildings Committee with the support of DOWEL Innovation.

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Contents

Glossary

Integrated design: Integrated design is a comprehensive holistic approach to design which brings together specialisms usually considered separately. It attempts to take into consideration all the factors and modulations necessary to a decision-making process.

Twin transition: Twin green and digital transition providing a green productivity premium to discrete manufacturing, construction and energy-intensive industries, including process industries, according to the European Commission.

List of acronyms

API Application Programming Interface

BPD Building Performance Database

BPS Building Performance Simulation

CDW Construction & Demolition Waste

E2B Energy Efficient Building

EU European Union

IS Industrial symbiosis

LCA Life Cycle Assessment

LCC Life Cycle Cost

NZEB Nearly zero-emission building

PEBs Positive Energy Blocks

PPP Public-Private Partnership

PV Photovoltaics

R&I Research and Innovation

S-LCA Social Life Cycle Assessment

TRL Technology Readiness Level

US Urban symbiosis

ZEB Zero-emission building

Introduction

Overall context and challenges

The built environment is responsible for a significant share of our consumption of energy and resources: 50% of all extracted materials, 30% of water consumption, 40% of energy consumption and 36% of CO_2 emissions in the use phase. At the same time, the embodied carbon in the built environment has been estimated to 10-12% of total carbon emissions in several member states. Construction and deconstruction/demolition waste are one of the heaviest and most voluminous (25-30%) waste streams generated in the EU [1].

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.

Under FP7 and Horizon 2020, energy performance of buildings was supported by the Energy-efficient Buildings (EeB) PPP[2]. The PPP succeeded in advancing the TRL of a number of energy-efficient and low-carbon solutions for the buildings sector, with a focus on components, materials and technologies. However, the PPP, targeting the technology development, did not address the role of buildings and infrastructure in the societal and economic transition to environmental sustainability and carbon neutrality. There is a need to develop a truly integrated, holistic and people-centric approach to the design, construction, operation and maintenance, renovation, disassembly and recyclability of buildings. The Built4People partnership (B4P partnership) will bring together the whole value chain to radically accelerate progress on the more holistic R&I agenda for a people-centric sustainable built environment, adapted to places, cultures and uses. The partnership will work across disciplines and life cycle stages, and across various scales, from building, block of buildings, and district, and bringing components and modules to city and wider regional, national and European levels. Deep changes in the way materials are produced are needed as well to align the energy performance requirement of the EU building stock to the longer-term climate neutrality goal and increase the resilience and sustainability of the built environment.[3]

To reduce embodied emissions and the environmental footprint of the built environment, and to increase the sustainability of the built environment with a 'more than human' [4] approach encompassing ecological imperatives, research and innovation must tackle the following cross-cutting challenges as well:

- lack of reliable data;

[1] Draft proposal for B4P partnership (2020)

[2] http://e2b.ectp.org/

[3] Please refer to the Materials & Sustainability position paper

[4] Fieuw et al.,2022 https://doi.org/10.3390/su14020948

- lack of qualified/trained people who can adopt the solutions developed;
- business models and contracts that are not adapted to sustainable ways of designing and delivering built works;
- weak buy-in of the stakeholders, in particular of the building inhabitants and apartment owners, undermining the implementation of top-down energy efficiency policy;
- legal framework (including public procurement rules) not adapted to innovative solutions and approaches;
- the shift to a circular economy and the needs to accelerate innovation pathways to massively transform the built environment with the particular focus on the "repair", "reuse" and "renovate" rather than on new products manufacturing.

Scope and Approach

The E2B Committee sees the need to extend from Energy-efficient Buildings to Sustainable (user centric & circular) built environment and ultimately Carbon Neutral Cities, enabling the technology developments that are needed to face Europe's challenges and ambition by 2030 and 2050.

This Position Paper aims to give an overview of the research and innovation paths that the ECTP Committee on Energy Efficient Buildings (E2B) recommends by 2027 in order to tackle the above-mentioned challenges.

To elaborate those recommendations, a workshop was organised with the Executive Board of the E2B Committee, followed by a collaborative process involving all E2B Committee members, and a consultation of key external stakeholders.

This position paper looks to:

- Identify research needs to drive the social impact of the built environment to the forefront of European research and innovation agendas.
- Focus on future innovations and technologies for the built environment.
- Raise awareness and communicate priorities to strategic stakeholders.
- Promote science translation of research results, ensuring the smooth implementation of up-to-date, evidence-informed policies and practices.
- Support research-funding proposals and partnerships.
- Advocate and share knowledge within and beyond the ECTP.

High-level objectives formalised by Energy Efficient Buildings committee

Considering the outlined needs and aspirations, the Committee has identified six high-level objectives that are critical to enhance the sustainability of districts and cities namely:

- **Objective 1: Near zero and positive built environment**
- **Objective 2: New renewable and clean distributed energies**
- **Objective 3: Circularity & resource efficiency in built environment**
- **Objective 4: Regenerative and nature-based built environment**

- **Objective 5: Implementing people-centric approach**
- **Objective 6: Integration of cross-cutting issues**

For each of these objectives, a set of priority areas are identified for the future research and innovation activities of the sector: they each correspond to specific challenges and are complemented by a list of focused R&I topics.

The next diagram provides an overview of the priority areas identified for each objective. The next sections of this Position Paper detail these objectives, R&I priority areas and topics.

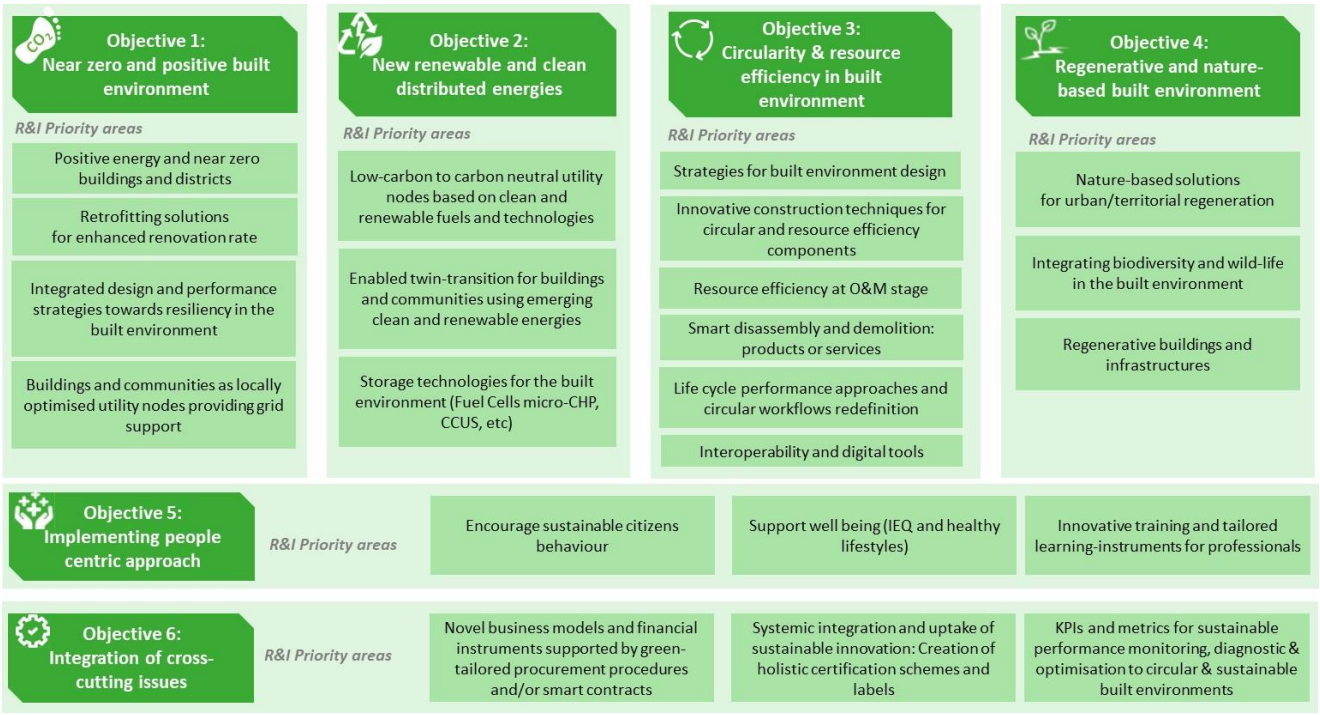

FIGURE 1: High-level objectives formalised by the Energy Efficient Buildings committee, and related priority areas for research and innovation.

1. Objective 1: Near zero and positive built environment

In December 2021, the European Commission proposed to revise the Energy Performance of Buildings Directive to align its rules with the European Green Deal[5] and decarbonise the EU's building stock by 2050. This proposal aims to facilitate the renovation of the European buildings stock and makes a step forward from current Nearly Zero-Emission Building (NZEB) (i.e. building that has a very high energy performance) to Zero-Emission Building (ZEB), aligning the energy performance requirement for new buildings to the longer-term climate neutrality goal and "energy efficiency first principle".

Positive Energy Buildings, producing more energy than necessary to their needs with mutual support of other buildings connected to them (thereby creating Positive Energy Blocks (PEBs)), could be an important step during the transition phase to the full decarbonisation. With their positive energy balance, they could accelerate the transition, supporting those buildings that are still waiting for the renovation wave to reach them, or e.g. historical buildings, which will not be able to reach the ZEB level. A holistic view is necessary in developing Positive Energy Buildings and Blocks, not aiming at the positive balance at any cost to the economy or environment.

To decarbonise the EU's building stock by 2050, the upcoming R&I activities should focus on the following four priority areas:

- Positive energy and near zero buildings and districts
- Retrofitting solutions for enhanced renovation rate
- Integrated design and performance strategies towards resiliency in the built environment
- Buildings and communities as locally optimised utility nodes providing grid support (flexibility) including optimising the communities networks in the fringes of large urban centres.

These four R&I priority areas are detailed in the next sections.

1.1. Positive energy and near zero buildings and districts

According to the proposal for a recast of the Energy Performance of Buildings Directive (EPBD), a Zero-Emission Building (ZEB) is defined as a building with a very high energy performance, with the very low amount of energy still required fully covered by energy from renewable sources and without on-site carbon emissions from fossil fuels. The ZEB requirement should apply as of 1 January 2030 to all new buildings, and as of 1 January 2027 to all new buildings occupied or owned by public authorities.

A Positive Energy Block (PEB) is defined by the European Commission[6] as a group of at least three connected neighbouring buildings producing on a yearly basis more primary energy than what they use. These buildings must serve different purposes (housing, offices, commercial spaces...) to take advantage of complementary energy consumption curves and optimise local renewable energy

[5] european-green-deal-communication_en.pdf (europa.eu)

[6] Smart Cities Marketplace : https://smart-cities-marketplace.ec.europa.eu/action-clusters-and-initiatives/action-clusters/sustainable-built-environment/positive-energy

production, consumption and storage. At the demonstration stage for now, there is a massive challenge to scale up the concept.

Research topics in this area include:

- Develop new positive energy strategies in districts, including technology, spatial, regulatory, financial, legal, social and economic perspectives
- Demonstrate the benefits of building or district energy production systems combined with energy storage solutions and grid integration, by means of incorporating flexible energy assets into building performance management (such as PV to Green Hydrogen distributed production)
- Develop and demonstrate solutions enabling the integration of PV in buildings (e.g. facades windows, shading systems, etc)
- Develop and demonstrate solutions enabling the installation of concentrated solar thermal for heating water or mCHP (micro–Combined Heat and Power) systems that can use mixed natural gas and hydrogen (or pure Green Hydrogen) for buildings
- Develop decision-making tools to evaluate and optimize energy management in buildings and for energy district level load matching with renewable energy generation
- Define user-centric processes engaging all the stakeholders, including the non-technical stakeholders (i.e. building owners and residents), from the design stage to demonstration, in upgrading the performance of buildings and districts to NZEB & ZEB
- Develop easy to use design tools and methodologies to prioritise passive (architectural) energy efficiency measures over active measures (HVAC system)
- Develop holistic energy management systems at district scale
- Demonstrate zero energy districts through renewable systems, with a special focus on solar energy
- Demonstrate the effectiveness of interconnected net of buildings exchanging data and information to optimise energy performance at building block scale
- Develop standard framework for simulation-aided building design integrating novel occupants' behaviour modelling to overcome the Energy-Gap between design and building performance towards successful positive energy balance

1.2. Retrofitting solutions for enhanced renovation rate

To boost renovation in the EU, the Commission aims to double annual energy renovation rates in the next 10 years.[7] In the revised EPBD directives, the European Commission proposed new EU-level minimum energy performance standards, requiring the worst-performing 15% of the building stock of each Member State to be upgraded from the Energy Performance Certificate's Grade G to at least Grade F by 2027 for non-residential buildings and 2030 for residential buildings. This initial focus on the lowest performing buildings fulfils the twin objective of maximising the potential for decarbonisation and for the alleviation of energy poverty.

To reach this target, one of the key challenges is to provide easier access to information and lower costs for consumers to help to boost renovation.

[7] A renovation wave for Europe – greening our buildings, creating jobs, improving lives. October 2020

Research topics in this area include:

- Develop multifunctional building solutions (such as envelope solutions integrating PV) for affordable renovation, avoiding disturbances to building users while increasing user engagement towards enhanced energy behaviours
- Develop solutions and methodologies to retrofit, upgrade and smarten existing systems and equipment (starting on the more energy demanding ones like HVAC) to avoid their replacement
- Develop and implement technologies and business models for 100% offsite prefabricated energy renovation
- Develop technologies for mass-deployable, easy and quick upgrading of inefficient heating and cooling systems
- Demonstrate the applicability of biobased materials and materials with reduced embodied energy in particular for retrofitting of historical buildings
- Develop 3D- printing solutions, improving production processes and equipment to increase material efficiency, equally suitable for renovation
- Demonstrate retrofitting technologies and holistic approaches to maximize renovation rates at district level and provide policy and market uptake recommendations
- Standardise socio-cultural drivers and barriers affecting the user acceptance of retrofitting technologies
- Demonstrate novel business models enabling tech-permeability into EU markets
- Develop information material to different stakeholders and market actors about the benefits of different energy efficiency improvement methods and renewable integration, and their applicability to different types of buildings (i.e., building traditions)

1.3. Integrated design and performance strategies towards resiliency in the built environment

The IPCC[8] defines resilience as *the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.*

Resilience encompasses many aspects outside of a structure's physical ability to withstand natural hazards or other threats: it also includes the anticipatory strategies used to maintain operation of equipment, building systems and infrastructures (including energy and water networks). Potential threats include both disruptions over short time horizons (e.g. heavy rainfalls, earthquakes, cyber-attacks) and slow moving, more diffuse threats (induced by climate change for instance).

[8] IPCC, 2018: Annex I: Glossary [Matthews, J.B.R. (ed.)]. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)].

Resilience should therefore go beyond its application in structural engineering, and be implemented as a long-term design principle, ensuring comfort and encompassing the wider district scale and digital infrastructure.

Research topics in this area include:

- Develop resilience scenarios and solutions dealing with energy scarcity situations that may occur in the future (i.e., Buildings that adapt to low power consumption modes)
- Develop assessment tools to evaluate the threats to the built environment and energy systems due to climate change and natural hazards
- Develop integrated approaches and nature-based solutions (from design to solutions) for increased resilience at building and district scale against climate change and natural hazards (extreme heatwaves, heavy rainfall, earthquake, etc...)
- Develop integrated building design methods and performance strategies towards resilient and positive energy communities by incorporating occupant behaviours as key resilience assets.

1.4. Buildings and communities as locally optimised utility nodes providing grid support

Buildings are becoming more and more active, participating to the management of utilities, as well as enabling synergies between them. To reach the target of climate neutrality – even beyond with positive energy – building must complete their transformation into smart-grid ready and smart-network ready buildings, acting as active utility nodes. 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. This calls for action at a larger scale than buildings, to maximise the benefits of sharing within a block of buildings the energy generated from local resources. This would enable a better integration of the built environment with the urban networks, in particular energy (allowing building to provide support services to the grid) and mobility (e.g. provision of charging outlets, vehicle to grid and transportation networks dynamically interacting with the power network).

Research topics in this area include:

- Use Energy Management System (EMS) for the monitoring and control of energy nodes using also the battery on wheels paradigm for electrical vehicles
- Demonstrate the possible interaction of power distribution and railway distribution networks at least in a number of metro/railway stations in Europe
- Structure and increase the potential of energy flexibility assets within positive energy communities. Develop novel socio-technical approaches to enhance energy demand flexibility. Focus on connection to e-mobility.
- Demonstrate buildings as energy production nodes, integrated with energy storage solutions such as distributed green hydrogen production and storage (PV to Green Hydrogen)
- Develop tools to evaluate the value of energy flexibility actions at building and district scale under different energy market structures

- Explore mechanisms to democratise (i.e. in availability, in complexity and in transparency) the use of demand response management systems in order to support local electricity markets and communities
- Develop energy market transactions information mechanisms to support decisions in the demand response consumer side (i.e. having a consumer-centric approach)
- Explore demand response management systems using psychology and behavioral economics to assure greater prediction accuracy

2. Objective 2: New renewable and clean distributed energies

So as to reach the decarbonisation targets, the built environment must fully integrate renewable and clean energy sources and become an integral part of the distributed energy system.

The EPBD proposal requires that new buildings install heating systems with zero direct greenhouse gas emissions and integrate renewable energies to become Zero-Emission Buildings, which shall become the new standard for new buildings as well as the level to be attained by a deep renovation as of 2030. Different options are available to cover the energy needs of an efficient building by energy from renewable sources: on-site renewables such as solar thermal, solar photovoltaics, heat pumps and biomass, renewable energy provided by renewable energy communities or citizen energy communities, and district heating and cooling based on renewables or waste heat.

The deployment of alternative fuel infrastructure (electric recharging infrastructure, clean hydrogen) also calls for a better integration of renewable and clean distributed energies, with 'utility nodes' as a cornerstone.

However, a number of challenges remain to be tackled to harvest, store and use locally clean and renewable energy sources in a cost-effective way while preserving user comfort and well-being.

The upcoming R&I activities should focus on the following three priority areas:

- Low-carbon to carbon neutral utility nodes based on clean and renewable fuels and technologies
- Enabled twin-transition for buildings and communities using emerging clean and renewable energies
- Storage technologies for the built environment

These three R&I priority areas are detailed in the next sections.

2.1. Low-carbon to carbon neutral utility nodes based on clean and renewable fuels and technologies

While renewable energy technologies such as solar thermal, solar photovoltaics, biomass are now very mature and with a high penetration rate, other clean technologies – for instance based on hydrogen – are still at an incipient stage. Hydrogen produced with renewable energy is being pushed as a solution to many challenges in the energy transition, however it is – as of today – better suited to some uses more than others, in particular where direct electrification is not an option as too expensive. For instance, hydrogen has a big potential for grid-level storage and the decarbonisation of heavy-duty vehicles, but is for now not a cost-effective option for home heating. Its use in CHP and district heating is also raising a lot of interest among industrials (many turbine manufacturers are progressing on H_2-fired turbines, to enable using 100% H_2 instead of a small percentage of H_2 mixed with natural gas).

Research topics in this area include:

- Design and develop technologies for creating carbon neutral utility nodes integrated to and based on existing gas, heat and power distribution infrastructure
- Develop disruptive approaches towards enhanced low-carbon to carbon neutral utility nodes models in positive energy districts that strengthen citizens engagement
- Develop and demonstrate innovative HVAC systems using H_2 as primary energy source.
- Develop and demonstrate production of green H_2 (e.g., blended with natural gas, pure in CHPs or pure in fuel cells) at building/district level for heating/cooling and electricity in different climate areas of Europe and different types of buildings:
- Develop cost-effective solutions to make possible H_2 based energy districts
- Demonstrate hydrogen technologies as a storage medium: power to gas to power (e.g. PV energy to hydrogen to electricity) to manage peak demand or for seasonal energy storage
- Design Carbon Capture Utilisation and Storage infrastructure
- Develop technologies to integrate wind energy in the built environment

2.2. Enabled twin-transition for buildings and communities using emerging clean and renewable energies

Digital transformation in the built environment can boost sustainability by enabling a better integration of clean and distributed renewable energies to the energy system and optimising their local use by buildings and infrastructures. This “twin green and digital transition”, or “twin transition”, may be the key to decarbonising buildings and districts.

Renewable energy communities and citizens energy communities, introduced by the Renewable Energy Directive and the Electricity Market Directive respectively, have a key role to play. They are instrumental in providing locally produced energy and enable a true empowerment of citizens, also promoting a sense of belonging to a community that can support local, territorial approaches.

Research topics in this area include:

- Creation of standards for digital twins of renewable energy, generation, distribution and use systems
- Explore the combined potential of distributed renewable energy generation and storage within urban energy systems
- Develop new technological solutions (e.g. multifunctional envelopes) for massive deployment of PV in buildings.
- Demonstrate energy community models integrating clean and renewable energies in smart neighbourhoods, with a focus on PV energy and hydrogen production and storage, to ensure their general adoption
- Develop strategies for plug and play connections for building integrated energy production units (e.g. BIPV or BIPVT)
- Develop and demonstrate energy management solutions enhancing user empowerment at building and neighbourhood level for a safe and cost-effective integration of green and renewable energies in smart neighbourhood

2.3. Storage technologies for the built environment

With the uptake of distributed renewable energy sources (DRES) required to reach the ZEB targets, storage is more than ever a massive challenge. Indeed, the energy demand of buildings (as well as that of charging infrastructure) is likely to be misaligned with the generation from DRES. Although the combination of tertiary and residential profiles at the scale of the building block can reduce the mismatch, storage of electricity and heat, or as Power to-X, at building and district level, is a key technological brick.

Research topics in this area include:

- Demonstrate the several energy storage possibilities in order to support decision making in future investments (for domestic, industrial or other uses)
- Develop standards and technologies for safe hydrogen storage at building and district scale
- Update the knowledge and technology base regarding ground and building structure integrated thermal storage
- Develop kinetic energy storage technologies for local energy storage and transformation
- Overcome socio-cultural barriers affecting the user acceptance of storage technologies and demonstrate novel business models enabling tech-permeability into EU markets
- Develop technological solutions to take advantage of the mass and inertia of the buildings as energy storage systems
- Explore energy storage possibilities (for domestic households) not based on batteries

3. Objective 3: Circularity & resource efficiency in the built environment

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.

The European Commission adopted the new Circular Economy Action Plan (CEAP) in March 2020[9]. It is one of the main building blocks of the European Green Deal. It focuses on the sectors that use most resources and where the potential for circularity is high, including construction and buildings. A proposal for a revised Construction Products Regulation (CPR) was adopted on 30 March 2022.

Moving towards a more circular and resource efficient construction value chain implies embracing a life-cycle approach across all the life stages of a building, from building to demolition/ end-of-life, paying a particular attention to the operation and maintenance stages, but also looking for synergies with other sectors. New approaches that foster the acceptance from all stakeholders are instrumental.

The upcoming R&I activities should focus on the following six priority areas:

- Strategies for built environment design, including urban and industrial symbiosis, circularity, eco-design and flexibility
- Innovative construction techniques for circular and resource efficiency components (easy to install, modular solutions, etc)
- Resource efficiency at operational and maintenance stage in the built environment (i.e. increase of durability and decrease of resource consumption (power, water etc))
- Smart disassembly and demolition: products or services
- Life cycle performance approaches and circular workflows redefinition (from buildings & infrastructure to district levels)
- Interoperability and digital tools (such as. protocols between BIM, BPS tools, LCA, LCC & LSA)

These six R&I priority areas are detailed in the next sections.

3.1. Strategies for built environment design

Innovation in the built environment need to be supported by innovative approaches improving eco-design and flexibility to contribute to circularity and including industrial and urban symbiosis.
Industrial symbiosis (IS) is the integration of different industries into a common approach to exchange materials, energy, water, and/or by-products to achieve a competitive advantage. Urban symbiosis

[9] Circular economy action plan (europa.eu)

(US) recognizes the use of solid waste in cities as input sources for industries[10]. Both IS and US focus on waste recycling and a network of symbioses through feedstock savings and/or emissions reductions that provide benefits to society as a whole promoting circularity.
Particularly, US is a physical, economic, and political challenge with several obstacles due to the complexity of managing the interests of all stakeholders involved[11] aiming to break linear relationships between consumption and waste returning outputs as inputs, e.g. recycling wastewater or water from industrial processes[12]. Moreover, IS strategies in urban places could be a tool to improve their sustainability avoiding for instance the landfills for urban waste[13].
According to the EC Report "Study and portfolio review of the projects on industrial symbiosis in DG Research and Innovation: Findings and recommendations"[14], the potential of IS could be expanded towards "industrial-urban symbiosis", being the foundation for the hubs for circularity and involving the cooperation of municipalities and regions with industries.

Research topics in this area include:

- Develop flexible and modular building concepts to adapt and expand buildings to new uses or users' needs
- Develop novel methodologies of circularity by design for the built environment, considering engineering quality and safety considerations as well as environmental, economic and social factors
- Demonstrate the application of Minimum Environmental Criteria for green public procurement considering the full life cycle of the structure
- Propose standards, metrics and evaluation methods for the circularity of construction products, systems and materials
- Develop and demonstrate new approaches to building design based on the durability of components and materials
- Design innovative solutions, new materials and forms for an inclusive and resource efficient built environment and way of living in EU cities
- Develop and demonstrate fully circular cross-industry material flows in the built environment
- Demonstrate resource symbiosis approaches on infrastructure and materials for clean and sustainable built environment
- Propose cross data models and methodologies to have a whole circular economic value chain
- Demonstrate industrial symbiosis for constructions at regional level integrating local value chains (by-products from other industries to use as construction material)
- Demonstrate building retrofit solutions from regional industrial symbiosis loops

[10] Momirski, L.A., Music, B. , Cotic, B. Urban Strategies Enabling Industrial and Urban Symbiosis: The Case of Slovenia. MDPI. Sustainability, 2021, 13, 4616

[11] Mulder, K. Urban symbiosis as a strategy for sustainabilising cities: An overview of options and their potential, pitfalls and solutions. Civil Eng. Res. J. 2017, 2, 1–7.

[12] https://ec.europa.eu/environment/ecoap/news/urban-symbiosis-recommendations-cities-re-use-resources_en

[13] Albino, V.; Fraccascia, L; Savino, T. Industrial Symbiosis for a sustainable City: Technical, Economical and Organizational Issues. Elsevier. Procedia Engineering. 2015. Volume 118. Pages 950-957.

[14] https://op.europa.eu/en/publication-detail/-/publication/f26dfd11-6288-11ea-b735-01aa75ed71a1

- Develop smart circular solutions for efficient recovery of End-of-Life renewable photovoltaic cells in buildings

3.2. Innovative construction techniques for circular and resource efficiency components

At construction stage, innovative techniques are required to implement what has been carefully designed, and make sure the as-built performance matches the designed one. On-site and off-site construction processes need to be developed and industrialised to enable the cost-effective manufacturing and an easy installation of prefabricated modular components for instance, in a way that they partially use recycled materials, and can be easily dismantled and re-used (or recycled) when they have reached the end of their service life.

Research topics in this area include:

- Develop solutions and products facilitating the design for flexibility, expansion and convertibility of the building during its lifetime (potential for shifts in space planning, for changes in use, e.g., residential to commercial etc), accounting for user needs and expectations while enabling a greater acceptance of novel approaches
- Develop and demonstrate circular modular solutions to make possible building assembly in construction and disassembly at the end of its life
- Develop and propose solutions to scale-up the modular construction based on local materials, including sustainability assessment and suggestions for promotion of sustainability by policy makers
- Apply biofabrication techniques to architectural components and adapt design processes
- Demonstrate new closed-loop offsite based value chains for the construction of the built environment with recycled components and ICT tools, leveraging aesthetic and social acceptance barriers
- Develop solutions that increase the use of recycled materials but also for the accounting of the end of life of components, considering the dismantling and the recovery of resources and raw materials
- Demonstrate the applicability of green composites in construction
- Develop 3D-printing technologies for construction using recycled materials and minimizing the use of resources
- Develop national registers or platforms for sharing the information of available recyclable material

3.3. Resource efficiency at operational and maintenance stage in the built environment

During the building life, at operation and maintenance stage, the strive for resource efficiency continues, to go beyond energy efficiency (already addressed in Objective 1).

This includes using solutions that increase durability, reduce the needs for maintenance and replacement of components and materials, and also minimises the consumption of resources such as power or water.

Research topics in this area include:

- Create a mechanism that calculates a dynamic baseline for resource per capita consumption (based on the resource availability, weather, etc.) and propose automatic regulation mechanisms that feed the monitoring systems of the built environment and condition the resource consumption. For instance: to know how much water you can (should) use considering the actual situation of weather, water supplies, forecasts, etc.
- Develop data driven solutions predicting durability in green building products which account for occupant energy demand dynamics
- Develop coatings to minimize maintenance costs of buildings and their systems, as PV and solar collectors
- Develop and demonstrate X-as-a-service business models for long service life products and systems incorporating circularity and material efficiency principles

3.4. Smart disassembly and demolition: products or services

Finally, when a building reaches its end-of-life, traditional demolition processes should give way to smarter deconstruction and disassembly techniques, assisted by robotics and supported by innovative services, enabling the separation of Construction & Demolition Waste (CDW) and maximising the potential for re-use and recovery.

Research topics in this area include:

- Develop automated and robotic systems for the separation of CDW
- Develop and demonstrate digitally supported design for deconstruction and reuse, at component and material levels
- Develop digital-twin based demolition/deconstruction management tools to optimize the process and waste recovery
- Develop mechanisms that ensure tracing (to go and track) demolition and disassembly "residues"
- Demonstration of smart disassembly products and service at district level
- Standardisation of design for disassembly in buildings

3.5. Life cycle performance approaches and circular workflows redefinition

So as to reach the full potential of circularity and life cycle performance while taking into account the interconnected nature of the built environment, scaling up from the individual, 'isolated' building or infrastructure to the district level appears as a must-have.

Implementing a district approach enables the development of virtuous circular workflows and increases the possibilities to identify and support symbioses, for instance building heat pumps using waste heat from wastewater pipes or metro tunnels, city farms using food biowaste from residential buildings, etc. District life cycle assessment is still in its infancy although tools already exist to support the development of new building blocks or districts, focussing on the energy use or LCA-related environmental impacts.

Performing a Life Cycle Assessment (LCA) is today required in public procurement by some governments and integrated in whole-building assessment frameworks such as BREEAM or LEED at building level. In practice, it is commonly employed to study the primary energy uses and associated environmental impacts of the different phases of a building's life cycle. However, performing LCA is still a challenging and complex process considering the built environment or at district level, mixed with the possibility of significant errors—namely due to unreliable input data. The combination with digital tools such as BIM and Digital Twins offers interesting opportunities.

Research topics in this area include:

- Develop impact assessment frameworks accounting for inclusiveness and affordability for an enhanced circularity and sustainability of the built environment at district scale
- Demonstrate circular solutions for construction, integrating Life Cycle Sustainability Assessment (LCA-LCC-SLCA)
- Develop innovative smart solutions for efficient tracing of decarbonized building resources and products under life cycle perspectives
- Integrate design-for-deconstruction and components re-use approaches as assessment criteria for public procurements

3.6. Interoperability and digital tools

There is a need on the definition and application of adequate interoperability mechanisms and digital tools to foster the built environment digitalization to address circularity & resource efficiency materials[15]. BIM models, standards and other common data formats have proven to be technical enablers for the integration of heterogeneous data sources, formats and tools. Moreover, BIM has positive impacts on the three pillars of sustainability but its capacity for improving environmental performance would be enhanced through integration with other special tools, such as Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and social life cycle assessment (S-LCA)[16]. An automated link between LCA, LCC & LSA and BIM can be achieved when overcoming the technical, organisational, and informational required[17]. This could be addressed at design practice and support the necessary improvements in the sustainable built environment performance. Moreover, BIM combined with BPS tools (e.g., e-Quest, EnergyPlus, etc) have the choice to provide stakeholders energy saving alternatives improving the energy analysis and saving costs in projects acting at design level[18].

Research topics in this area include:

[15] Advanced materials 2030 Manifesto

[16] Alvarez Antón,L;Diaz, J. Integration of LCA and BIM for sustainable construction. World Academy of Scicence, Engineering and Technology International Journal of Civil and Environmental Engineering Vol 8. No5. 2014.

[17] Obrecht T.P et al. BIM and LCA integration: A systemic literature review. MDPI. Sustainability, 2020, 12, 5534.

[18] M N Udding, et al. An Inquisition of Envelope Fabric for Building Energy Performance Using Prominent BIM-BPS Tools-A case study in Sub-Tropical Climate. 2019 International Conference on Energy and Future Energy Systems: Earth and Environmental Science 354 (2019)012129.

- Develop and demonstrate new or adapted interoperable communication protocols (e.g., APIs) for BIM, BPS tools and LCA, LCC and LSA
- Integrate BIM based platforms and tools for integrated Life-Cycle Sustainability Assessment
- Integrate in BIM-decision making approach, mechanisms enabling to check the composition of a construction material, its environmental impact, its provenience, and its circular potential (such as in food, for instance)
- Demonstrate improved interoperable protocols in Building Performance Management techniques through end-user integration into energy simulation and management value chain
- Early integration of end-users in the design loop using ICT powered tools (BIM, Digital Twin) in new procurement processes (Integrated Design and Delivery Solutions)
- Develop seamless interoperability protocols between building models and IoT data

4. Objective 4: Regenerative and nature-based built environment

Unsustainable urbanisation, climate change, biodiversity loss and the degradation of ecosystem services are just some of the challenges our societies must now face. There is a strong interest in the theme of re-naturing cities, as it can help addressing these challenges and generate multiple co-benefits, such as the enhancement of health and well-being, sustainable urbanisation, the provision of ecosystems services, and resilience to climate change.

Using "Nature-based solutions" (NBS) is a way to bring nature back to the city to make the built environment a healthier and a better place to live. The NBS industry is maturing and the remaining challenges are rather related to financing, public acceptance and the readiness of local governments and stakeholders.

Beyond NBS, there is also a potential for the built environment to have a positive impact on biodiversity and provide regenerative functionalities, to turn buildings and infrastructures into integral parts of a more resilient ecosystem.

The upcoming R&I activities should focus on the following three priority areas:

- Nature-based solutions (NBS) for urban/territorial regeneration
- Integrating biodiversity and wildlife in the built environment
- Regenerative buildings and infrastructures

These three R&I priority areas are detailed in the next sections.

4.1. Nature-based solutions for urban/territorial regeneration

Nature-based solutions are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions [19]. They contribute to combat climate change, reduce flood risks, improve water quality, reduce urban heat, add recreational space, and much more. Nature-based solutions must also benefit biodiversity and support the delivery of a range of ecosystem services.

Many NBS have already been tried and tested already (in EU funded projects for instance[20]), however their implementation is not a simple matter of replacing an existing and established way of doing things. In most cases, NBS require a whole new mind-set and governance approach as well as new business and financing models.

[19] According to the EU Commission

[20] https://cordis.europa.eu/article/id/421853-nature-based-solutions

Research topics in this area include:

- Develop standardized NBS models to integrate NBS in the buildings and districts design and simulation tools (energy efficiency impact, maintenance costs, air quality...)
- Propose certification/standardisation schemes of NBS solutions and public incentives to foster the use of NBS instead of grey/traditional solutions
- Demonstrate the use of NBS for urban and territorial regeneration, in relation to their contribution to increasing resilience. In particular, develop tools for preventive assessment of NBS effects.
- Demonstrate and use NBS for valorisation of the marginal land
- Demonstrate how NBS reduce heat island effects at the district scale
- Develop disruptive approaches to NBS accounting for an enhanced citizens behaviour towards an improved user well-being and healthy lifestyles
- Demonstrate/ scale up vertical farming concepts in particular associated with cellular agriculture
- Develop integrated planning and design optimisation tools for use in participatory decision-making that identify, quantify, and prioritise the full range of potential co-benefits and trade-offs
- Develop comprehensive digital twins with capacity for predictive analytics that can be used for operational management of the built environment as a social-environmental-political-legal-technological-economic-industrial ecosystem. I.e., digitisation of all physical/structural, social, economic, environmental (NBS and natural features), political and legislative components of the built environment, including: linkages/ interrelationships and feedback loops among sectors and individual components in space and time; real-time descriptive data analytics; and, continuously updated AI-enabled predictive data analytics linked with regulatory limits and/or policy targets.

4.2. Integrating biodiversity and wildlife in the built environment

Conservation of biodiversity makes a critical contribution to moderating the scale of climate change and reducing its negative impact by making ecosystems (including human societies) more resilient (UN, 2018). Urban biodiversity is key in establishing a balance between built and natural environment and providing an attractive place to live in.

As previously mentioned, NBS already provide clear benefits to biodiversity. These benefits could be further enhanced through ambitious, holistic approaches coordinated at district of even city scale, for instance to better link and connect green spaces by creating green corridors or greening existing infrastructures, reintroduce species that provide key ecosystem services (e.g., pollinators), while fostering the active participation of citizens.

Research topics in this area include:

- Demonstrate the advantages of introducing biodiversity and wildlife in buildings (e.g., biofilters, green roofs, etc.)
- Demonstrate the impacts of closing the loop of water with plant-based system to be included in the built environment at the building and district scale

- Demonstrate improved solutions that integrate and enhance biodiversity and wildlife in urban built environment through community centric-design (i.e. engage and foster the active participation of local communities and city residents)
- Propose urban planning and design solutions to integrate wildlife corridors at urban scale
- Promote the integration of biodiversity in the urban environment with the introduction of green infrastructure, such as green roofs and vertical greening system, taking care of the pollinators
- Develop regeneration and urban planning strategies and tools to keep or recover local ecosystems
- Demonstrate future-proofing nature-based solutions, regenerative buildings and other biodiversity-enhancing initiatives - development of detailed, regionally-specific design and monitoring/management guidelines to ensure long-term effectiveness of decarbonisation efforts.

4.3. Regenerative buildings and infrastructures

Living, regenerative, and adaptive Buildings have recently gained traction in building design and architecture. They achieve a net-zero impact on the environment (for energy, water and waste) and also improve their surrounding damaged environment for example by restoring a site's natural hydrology or providing for lost wildlife and plant habitat. Adaptive buildings can be easily remodelled and adapted for new purposes for which they were not originally conceived – or to adapt to changes in climate (e.g. flood or drought resistant materials and designs, passive cooling). Last but not least, they are designed to ensure the wellbeing and health of their occupants.

Research topics in this area include:

- Demonstrate the use of buildings with carbon sequestration capabilities and to put design and construction to work as positive forces that repair natural and human systems
- Integrate Carbon Capture and Storage technology at building level, e.g. by limiting carbon-intensive materials or choosing carbon sequestering materials or even landscaping solutions with integration of plants/trees absorbing CO_2
- Create a standard for regenerative buildings
- Develop and demonstrate innovative regeneration schemes that improve sustainable citizens behaviour towards enhanced healthy lifestyles

5. Objective 5: Implementing people-centric approach

As pointed out in the B4P Partnership proposal, for the transition towards low carbon and sustainable living to succeed, it is crucial to have citizens on board and make sure that this transition (and the transition towards a building stock with net-zero impact to the environment) is accepted and feasible for all.

This requires additional efforts to promote and accelerate the uptake of highly energy and resource efficient solutions that are offered on the market at reasonable costs. This also requires to re-design the built environment to encourage sustainable behaviour, rationalise construction, mass-market the offer of sustainable products and solutions as well as increase the availability of trained professionals to ensure their safety and to deliver quality construction and installation of sustainable solutions achieving the designed performance. Finally, this implies to better integrate and understand the human factor in research and innovation as well as carefully consider end-user needs and expectations (in terms of comfort, health, wellbeing or accessibility).

People-centric approach must translate into end-users involvement in design, development and demonstration of innovation to ensure high potential for social acceptance and effectiveness of the solutions to achieve sustainability objectives and to ensure that possible barriers to the use of these solutions, in particular by persons with disabilities and older persons who can experience accessibility issues, are well taken into accounts.

The upcoming R&I activities should focus on the following priority areas:

- Encourage sustainable citizens behaviour
- The built environment supporting well-being (including IEQ and healthy lifestyles)
- Innovative training and tailored learning-instruments to coach professionals to deliver quality on sustainable and circular construction and maintenance operations

These free R&I priority areas are detailed in the next sections.

5.1. Encourage sustainable citizens behaviour

Citizen's engagement and empowerment is crucial both for creating the demand for sustainable solutions in the built environment and for these solutions to produce the lasting behavioural change towards sustainable living.

Innovative models to enable community-led urban development need to be explored. Although many innovative technological and socioeconomic solutions have been developed in the last decade, they have not been fully implemented in practice, which is hindering the adaptation of the built environment to new uses, challenges and requirements related to climate change and sustainability.

Research topics in this area include:

- Develop demonstration/Living Lab approach and quantification methods to monitor citizen behaviour in sustainable and circular built environments, with direct occupant's feedback
- Develop a visualisation/information solution linking user behaviours with energy use and/or generation to guide on optimized energy demand

- Deploy ICT solutions for achieving a behavioural change of building occupants
- Demonstrate in real environment the use of digital technologies for the operation and management of energy facilities in buildings taking into account occupant behaviours (deep learning solutions)
- Demonstrate holistic solutions for a greater social and citizen engagement towards sustainable user behaviours and energy efficient patterns in buildings
- Develop disruptive policies to strengthen a more sustainable citizens behaviour towards an enhanced user well-being and healthy lifestyles
- Develop tailored approaches to support, streamline and accelerate decision-making mechanisms in condominiums with regards to energy (and environmental) performance, with clear framework laying out the responsibilities and how the risks are shared

5.2. The built environment supporting well-being (IEQ and healthy lifestyles)

There is a direct connection between the built environment and health, which goes far beyond indoor air quality and comfort within a building. Maintaining the IEQ must of course be ensured also when using the new strategies of positive energy balance, circularity and regenerative solutions. New solutions still need to be developed for catching the end users' satisfaction and feedback. The built environment as a whole indeed influences the public's health, particularly in relation to chronic diseases (e.g. respiratory diseases, obesity, cardiovascular diseases etc.). Most of these diseases could be avoided or reduced through an active lifestyle, proper nutrition, and reduced exposure to pollution. The built environment has a key role to play in supporting human health as part of everyday living, through improved walkability and cyclability, opportunities for physical activities, reduced air and noise pollution, healthy food access, safety and social cohesion. However, many urban and suburban environments are not well designed to facilitate healthy behaviours.

Research topics in this area include:

- Enhance and demonstrate innovative green facades to improve the indoor climate control integrating the circular economy principles
- Demonstrate improved IEQ in buildings and urban comfort in neighbourhoods through end-user integration into positive energy strategies
- Design new strategies for end user integration and social benefits to improve energy efficiency and IEQ in buildings
- Pilots as a Living Lab approach for the assessment of energy balance and IEQ of regeneration solutions in real environment with direct occupant's feedback
- Integrate smart and digital technologies for the energy management of buildings and blocks of buildings accounting for enhanced indoor conditions
- Propose initiatives that ensure citizen understanding and adoption of healthy lifestyles and how such behaviours can contribute to sustainability. Provide real world case studies presented in a convincing way (e.g. using real-life influencers)

5.3. Innovative training and tailored learning-instruments to coach for professionals

To reach the ambitious targets of zero energy buildings and a circular economy, actors across the whole value chain must be engaged and empowered to deliver at the required level of quality. Unfortunately, the current lack of qualification in the workforce related to new digital tools, circularity or NBS impedes the take up of sustainable and circular construction at the required pace. This also applies to the maintenance phase, where obsolescence often prevails.

Innovative training, including funding mechanisms, and tailored learning-instruments to coach professionals are therefore urgently needed. They should also guarantee that the construction sector is human-centric and places the wellbeing of the worker at the centre of the production process.

Research topics in this area include:

- Design and develop innovative training and tailored learning-instruments addressing construction sector professionals for an enhanced quality & sustainable operation in the built environment
- Development and implementation of innovative training activities to coach professionals in innovative built environment
- Develop peer-learning and mentorship approaches

6. Objective 6: Integration of cross-cutting issues

To accelerate people-centric innovation in the built environment and achieve on time the ambitious targets laid out in EU policies, transversal, non-technical challenges, relevant for most of the previously presented objectives, must be tackled first. They relate to financing, value chain integration and upskilling, standardisation and certification.

Objective 6 covers these cross-cutting issues and aims at fostering an enabling social and economic framework for the transition towards a sustainable built environment.

The upcoming R&I activities should focus on the following three priority areas:

- Novel business models and financial instruments supported by green-tailored procurement procedures and/or smart contracts
- Systemic integration and uptake of sustainable innovation: Creation of holistic certification schemes and sustainable/circular labels for products, services, buildings and infrastructure
- KPIs and metrics for sustainable performance monitoring, diagnostic & optimization to circular & sustainable built environments

These three R&I priority areas are detailed in the next sections.

6.1. Novel business models and financial instruments supported by green-tailored procurement procedures and/or smart contracts

Inclusive, affordable and user-centric business models (BM) and smart financing mechanisms are required to support and accelerate the uptake of innovative solutions and the transformation of the built environment, so as to attain the required pace needed for Europe to reach its goal of climate neutrality.

For BM innovation to deliver successful business models that can quickly be rolled out, it is critical to ensure that business models are user-centric and co-created with stakeholders. This requires for instance identifying value proposition for each stakeholder/ organisation in the value chain, understanding their pains & gains, and finding ways to better involve stakeholders in the buildings' lifetime.

This transition also requires the active support of public authorities with renewed procurement processes that give a real chance to innovation roll out. New business models should emerge in partnership with other sectors in order to offer combined, packaged services (including financing, data management, safety and security, etc).

Research topics in this area include:

- Design new circular, user-centric and sustainable business models for residential and non-residential built environments
- Demonstrate and expand the use of Minimum Environmental Criteria in green public procurement

- Develop inclusive and affordable energy services (ESCOs, PPP models etc), business models and policy frameworks for an enhanced circularity and sustainability
- Design new business models for sustainable built environments that integrate co-benefits (social, economic and environmental), sharing costs and benefits among relevant stakeholders.
- Develop Energy Community models integrated by fiscal incentives for CO_2 reduction and integration of circular solutions
- Standardise a co-benefit framework for the uptake of deep renovation strategies and innovative business models

6.2. Systemic integration and uptake of sustainable innovation: Creation of holistic certification schemes and labels

Standardisation and certification ease logistical procedures, facilitate trade, prevent consumer deception and improve quality (FAO, 2021).

Standards, certification schemes and labels therefore have a key role to play in the sustainable transition of the built environment, as they lay out frameworks with clear procedures or specifications, easy to understand and common to the whole value chain. They also provide an enhanced visibility and more transparency towards the end-users. However, today's certification schemes and labels related to sustainability in the construction sector are not sufficient as they do not provide a holistic approach (i.e. they will focus on the smartness of a building, or its environmental impacts, or will focus on new buildings or only tertiary ones), or cover too partially circularity and other key concepts of sustainability in the built environment. Holistic certification schemes and sustainable/circular labels for products, services, buildings and infrastructures are then needed.

Research topics in this area include:

- Develop a holistic approach to certification schemes, tackling not only the definition of the certification scheme, but also its deployment and mechanisms for its systemic integration and sustainable/circular labels for products, services, buildings and infrastructure to increase its acceptance by citizens.
- Propose a new label for buildings that certifies the circularity by design approach integrating design-for-deconstruction and components re-use as assessment criteria for public procurements
- Demonstrate new certification schemes for healthy buildings which empower citizens for an enhanced energy resources management
- Evaluate management processes and propose evidence-based guidelines

6.3. KPIs and metrics for sustainable performance monitoring, diagnostic & optimisation to circular and sustainable built environments

To monitor progress and performance of the construction ecosystem towards sustainability and the twin transition, key performance indicators and metrics are needed. In particular, KPIs are missing to measure social aspects such as citizen engagement and wellbeing.

Research topics in this area include:

- Develop new and adapted KPIs and metrics for diagnostic, monitoring and evaluation of the grade of sustainability in a built environment
- Propose KPIs based on energy consumption and generation, indoor air quality, and resilience of buildings
- Develop tailored KPIs and metrics for sustainable buildings focused on diagnostic & optimization energy performance strategies
- Develop a holistic methodology and support tool for global assessment of the built environment
- Develop metrics for sustainability assessment at building and district level and propose tools and methodologies for raising awareness of building users and policy makers

7. Conclusion

7.1. Timing of the different R&I priorities

Members of the E2B Committee were asked about the most relevant scheduling for the above identified R&I activities, according to three time horizon: the next Horizon Europe's Work programme (2023-2025), the following one (2025-2027), or after the end of the current framework programme (beyond 2027).

The table below synthesises their views. The colour code is as follows:

>75% of votes	between 50 and 75% of votes	between 25 and 50% of votes	<25% of votes	No votes

Objective 1: Near zero and positive built environment

	2023-2025	2025-2027	Beyond 2027
Positive energy and near zero buildings and districts	63%	38%	0%
Retrofitting solutions for enhanced renovation rate	50%	50%	0%
Integrated design and performance strategies towards resiliency in the built environment	50%	50%	0%
Buildings and communities as locally optimised utility nodes providing grid support	25%	63%	13%

Objective 2: New renewable and clean distributed energies

	2023-2025	2025-2027	Beyond 2027
Low-carbon to carbon neutral utility nodes based on clean and renewable fuels and technologies	63%	13%	25%
Enabled twin-transition for buildings and communities using emerging clean and renewable energies	38%	50%	13%
Storage technologies for the built environment	38%	63%	0%

Objective 3: Circularity & resource efficiency in built environment

	2023-2025	2025-2027	Beyond 2027
Strategies for built environment design	88%	13%	0%
Innovative construction techniques for circular and resource efficiency components	75%	25%	0%
Resource efficiency at O&M stage	50%	50%	0%
Smart disassembly and demolition: products or services	50%	50%	0%
Life cycle performance approaches and circular workflows redefinition	25%	63%	13%
Interoperability and digital tools	25%	63%	13%

Objective 4: Regenerative and nature-based built environment

	2023-2025	2025-2027	Beyond 2027
Nature-based solutions (NBS) for urban/territorial regeneration	75%	25%	0%
Integrating biodiversity and wild-life in the built environmenty	75%	13%	13%
Regenerative buildings and infrastructures	13%	63%	25%

Objective 5: Implementing people-centric approach

	2023-2025	2025-2027	Beyond 2027
Encourage sustainable citizens behaviour	63%	38%	0%
The built environment supporting well being (IEQ and healthy lifestyles)	75%	25%	0%
Innovative training and tailored learning-instruments for professionals	50%	38%	13%

Objective 6: Integration of cross-cutting issues

	2023-2025	2025-2027	Beyond 2027
Novel business models and financial instruments supported by green-tailored procurement procedures and/or smart contracts	50%	50%	0%
Systemic integration and uptake of sustainable innovation: Creation of holistic certification schemes and labels	0%	75%	25%
KPIs and metrics for sustainable performance monitoring, diagnostic & optimisation to circular & sustainable built environments	25%	75%	0%

7.2. Synergies between the Energy Efficient Buildings position papers and other ECTP committees

The next diagram synthesises the main topics that are addressed by several ECTP Committees and their respective Position Papers. For the Energy Efficient Buildings Committee, the synergies are:

- Retrofitting solutions for an enhanced renovation rate in Europe with the Heritage and Regeneration and the Material and Sustainability committees. For E2B the focus is on providing easier access to information and lower costs for consumers to help to boost renovation;
- Climate mitigation and energy integration and management with the Infrastructure and Mobility Committee: E2B focuses on the integration of renewables and storage and facilitate more active customer (prosumer) engagement, on linking buildings with the surrounding transport system and smart energy grids, as well as to fully integrate the circular economy principles in the built environment and the construction sector;
- Digital and automated solutions for smart operation and maintenance of the built environment and upskilling of the workforce with the Digital Built Environment committee.
- The Quality of Life and integration of biodiversity with the Built for Life committee. For E2B, the focus is to provide regenerative functionalities, to turn buildings and infrastructures into integral parts of a more resilient ecosystem.

	Energy Efficient buildings	Digital built environment	Material & sustainability	Built4Life	Heritage & Regeneration	Infrastructure & mobility
Infrastructure & mobility	Climate mitigation Energy integration & management	Inclusiveness Asset management Skills & safety Strategic planning	Resilience & climate mitigation Circularity	Inclusiveness & accessibility	Cross-impact assessment	
Heritage & Regeneration	Retrofitting solutions & skills	Inclusiveness Digital preservation Retrofit & Maintenance	Resilience & climate mitigation Circularity	Comfort & accessibility Regeneration		
Built4Life	Quality of life Energy communities Biodiversity	Quality of life Inclusiveness & adaptation Smart places	Inclusiveness & adaptation Indoor env. quality Climate adaptation			
Material & sustainability	Retrofit, RES, CCUS Circularity	Construction & renovation processes, incl. circularity				
Digital built environment	Smart buildings Skills & safety					
Energy Efficient buildings						

FIGURE 2 SYNERGIES BETWEEN ECTP COMMITTEES

7.3. Link with other initiatives

While the EU has led the world in addressing the operational emissions from buildings, it is crucial to accelerate the deployment of impactful renovation strategies to increase the renovation rate, to improve the energy efficiency standards and to change the focus from buildings to neighbourhoods. The high-level objectives and R&I priority areas discussed in this E2B position paper are in line with the World Green Building Council response to EPBD and EED review [21].

Finally, the following initiatives should be mentioned where synergies exist:

- Clean Hydrogen Partnership
- Towards zero emission road transport Partnership (2Zero)
- Eumat
- Process4people
- Made in Europe Partnership
- Inside Technology Platform
- AI, Data and Robotics Partnership:
- Euroace
- Fuel Cells & Hydrogen Joint Undertaking
- ETIP Photovoltaic (ETIP PV)
- ETIP Renewable Heating and Cooling
- ETIP Smart Networks for Energy Transition (SNET)

[21] World Green Building Council Feedback to Energy Performance of Buildings Directive (EPBD) Review

World Green Building Council Response to Energy Efficiency Directive (EED) Review