Strategic Research & Innovation Agenda 2021-2027

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Glossary

Baukultur: is defined as every human activity that changes the built environment, including every built and designed asset that is embedded in and relates to the natural environment

Building Information Modelling: process supported by various tools and technologies for creating and managing information on a construction project across the project lifecycle.

Citizens Energy Communities: legal entity which is autonomous, based on voluntary and open participation, effectively controlled by members who are natural persons, local authorities, or SMEs, and engaged in distributed electricity generation, supply, consumption, aggregation, storage or energy efficiency services, generation of renewable electricity, electro-mobility, distribution system operation, or any other energy services provided to its members.

Dynamic built environment is meant as a built environment that is designed, built and operated within a dynamic relationship with citizens.

Economic impact: positive effect of the R&I activities on the construction industry and its competitiveness.

Environmental impact: contribution of the R&I activities to limit the effects of the construction industry and built environment on the environment and climate.

Green Public Procurements: Green Public Procurement (GPP) or green purchasing is a voluntary instrument whereby local authorities use their purchasing power to choose environmentally friendly goods, services and works to make an important contribution to sustainable consumption and production.

Inclusive environment: An inclusive environment recognises and accommodates differences in the way people use the built environment. It facilitates dignified, equal and intuitive use by everyone. It does not physically or socially separate, discriminate or isolate. It readily accommodates and welcomes diverse user needs — from childhood to adulthood through to old age, across all abilities and disabilities and embracing every background, gender, sexual orientation, ethnicity and culture[1].

Industry 4.0: industry 4.0 refers to the concept of factories in which machines are automated and augmented with cyber-physical systems, the internet of things (IoT), cloud computing, cognitive computing and artificial intelligence, and connected to a system that can visualise the entire production line and control it.

Integrated Design and Delivery Solutions (IDDS): holistic approach of the construction process, relying on a combination of initiatives such as skill development, process re-engineering, responsive information technology, enhanced interoperability and integrating knowledge management, to reach a radical improvement of performances in the construction industries.

[1] After : https://www.designingbuildings.co.uk/wiki/Essential_principles,_Creating_an_accessible_and_inclusive_environment

IoT: Internet of things: system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction

Servitisation: The servitisation of products describes the strategy of creating value by adding services to products or even replacing a product with a service.

Smart grid ready: capacity to be integrated in a smart grid

Smart network ready: by extension of the above definition, designs the capacity to be integrated with smart networks (other than energy).

Societal impact: positive effect of the R&I activities on the social fabric of the community and well-being of the individuals and families (including, but not limited to poverty reduction, affordability of solutions, inclusiveness and accessibility, preservation and sharing of cultural assets)

Swarm robotics: research and development field to design groups of robots that operate without relying on any external infrastructure or on any form of centralised control. In a robot swarm, the collective behavior of the robots results from local interactions between the robots and between the robots and the environment in which they act.

Urban mining: concerns all the activities and processes of reclaiming compounds, energy, and elements from products, buildings, and waste generated from urban catabolism (Baccini & Brunner, 2012)

List of acronyms

Acronym	Description
AI	Artificial Intelligence
EED	Energy Efficient Directive
EPBD	Energy Performance of Buildings Directive
BEMS	Building Energy Management System
BIM	Building Information Modelling
CDW	Construction and Demolition Waste
IDDS	Integrated Design and Delivery Solutions
IoT	Internet of Things
LCA	Life Cycle Approach
PED	Positive Energy Districts
RES	Renewable Energy Sources
R&I	Research & Innovation

List of abbreviations for the types of R&I activities

R&D: stands for Research & Development

Demo: stands for demonstration activities

Integration: refers to activities focusing on integrating available technologies or components into 'real life' systems;

Business models: refers to the design, test and replication of new business models, including related marketing and socio-economic studies (market; end user behaviour and acceptance), as well as the integration of different stakeholders into shared business activities; and replicating practices/ businesses from other sectors.

Scaling up: refers to deployment at large scale of solutions (both in terms of technologies and business models) that were validated at small or local scale. In the case of technologies, scaling up also requires industrialisation

Foreword

ECTP as the key player in driving research, innovation and competitiveness across the construction sector, for the benefit of the Built Environment

The European Construction, built environment and energy efficient building Technology Platform (ECTP) is a leading membership organisation promoting and shaping the future of the Built Environment and Construction sector in Europe.

ECTP reconciles a collective vision for a leading edge European Built Environment on behalf of its Members (including buildings, transport infrastructures and infrastructures for all utility networks - energy, water, communication services, etc.). It gathers more than 140 Member organisations and individual members from across the construction sector and other sectors from the whole supply chain of the Built Environment. The main mission of ECTP is to identify, develop and implement new Research and Innovation strategies (R&I) to improve the competitiveness of the construction industry, meet the societal needs of a globally ageing population that evolves towards new living patterns, and take up environmental and resources challenges through an innovative and sustainable Built Environment.

ECTP is also one of the 40 European Technology and Innovation Platforms[2] (ETPs/ETIPs), which are industry-led stakeholders' fora that are recognised by the European Commission as key actors in driving innovation, knowledge transfer and European competitiveness. As such, ECTP oversees the management of the private part of the EeB cPPP (Energy-efficient Buildings – contractual Public-Private Partnership) established with the European Commission in 2009.

Why a Strategic Research and Innovation Agenda?

Low impact, high-performance buildings and infrastructures are pivotal in the socio-economic transition towards a sustainable and climate-neutral economy and society. A healthy, resilient built environment indeed provides the basis for other sectors to be successful and flourish.

Research and innovation investments to improve the competitiveness of a user-centric, sustainable construction sector are more than ever needed for Europe to compete in the international market and support the delivery of a prosperous, modern, competitive and climate-neutral economy by 2050, in line with the Paris Agreement objectives. In this context, one of the key activities of ECTP is to develop its sectoral *Strategic Research and Innovation Agenda* (SRIA) to take up the challenges and overcome the barriers that the Built Environment is facing in Europe, to define the most efficient actions to tackle them and as such help leading the way to industry growth and a more sustainable future.

The last multi-annual roadmap for the contractual PPP focused on Energy efficient Buildings under Horizon 2020 was published in 2013 and led to advancing the technology maturity and market

[2] Source : ERA-LEARN - Synthesis Report on the Partnership Landscape in view of the clusters in Horizon Europe (last update June 2019)

readiness of a number of solutions in terms of products and services, with a focus on building components, materials and technologies, as well as associated business models and market uptake measures.

This new version of the roadmap details the present and future needs of the **built environment as a whole (from building to infrastructures and cultural heritage)**, reflecting the complexity of the ECTP playground. Beyond energy efficiency and technological solutions, the SRIA also encompasses **socio-economic advances** and **new business models** to address non-technological barriers, and strives to deliver an **integrated and holistic, people-centric and life-cycle oriented approach** to the design, manufacturing, construction, operation, renovation and end-of-life management of the whole built environment. It therefore brings together a large community of stakeholders (both public and private) that engaged in a co-creation process to define R&I priorities and contribute to their financing.

This SRIA identifies and describes the future R&I priorities for developing and rolling-out the solutions that will help taking up the ***societal, industrial and technological challenges*** faced by the industry and the built environment, in a ***policy and regulatory framework that constitutes a strong driver***. This SRIA aims to ensure that the construction sector will, in the long-term, secure its competitiveness and sustainability, whilst the built environment (both buildings and infrastructures) provide secure, safe and smart living places for all citizens in Europe.

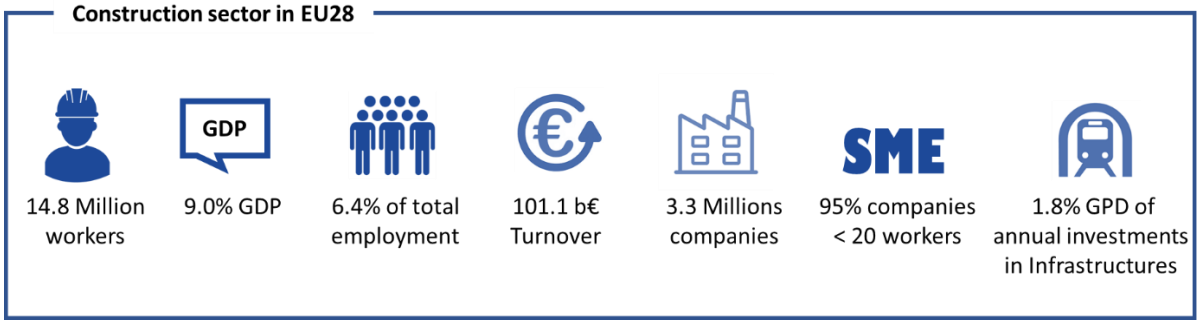
Photo: The construction workers, Fernand Leger, 1950

1. Today's built environment and construction sector

1.1. The construction industry

The construction industry is of fundamental importance to the EU economy. It generates **9% of the EU GDP** and around 5% of European workers and employees are directly employed in the construction sector, representing close to **18 million jobs**. Located at the crossroads of many different sectors, the construction ecosystem is **complex and multi-faceted** and includes a wide range of economic activities: from the extraction of raw materials (the construction sector is the largest consumer of raw materials in the EU) and the manufacturing and distribution of construction products, up to the design, construction, management of building and infrastructure projects, their maintenance, renovation and demolition, as well as the recycling of demolition waste.

With 95% of its 3.3 million companies having less than 20 employees, it is also a **highly fragmented** SME-based sector. This characteristic, added to the fact that construction is project-focussed, results today in the lack of an integrated vision (and collective action for R&I), and a limited uptake of innovation in the sector.



Source: Based on construction industry statistics from FIEC, ACE and EIB (figures 2017 and 2018).

The construction sector was hit particularly hard by the financial and economic crisis in 2008, but the recovery of the European economy has boosted growth in construction and since spring 2013 the index of construction production in the EU-28 has been relatively steadily increasing and has now almost reached 90 % of the former peak level. As for infrastructures, despite an annual 3% growth since 2013, overall investments still remain 20% below pre-crisis levels.

Noteworthy is to mention that 40% of the worldwide top-30 contractors are from the EU[3]. Since 2010, it has been the role of the contractual Public-Private Partnership instrument to coordinate Research & Innovation efforts for the construction sector as one way of supporting this leading position.

[3]http://www.ey.com/Publication/vwLUAssets/EY-reviewing-engineering-news-records-top-30-contractors/$File/EY-reviewing-engineering-news-records-top-30-contractors.pdf

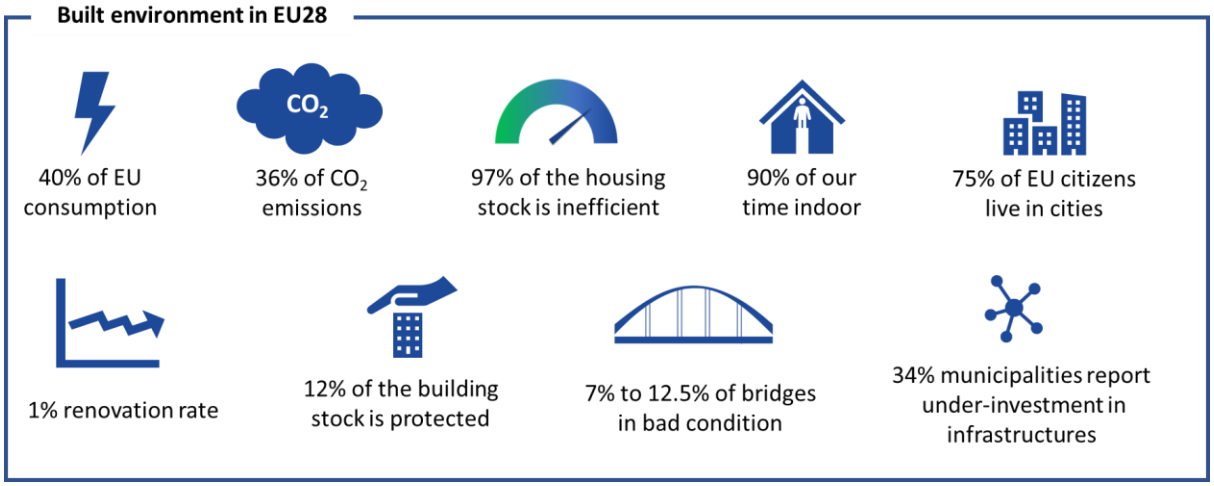
1.2. The built environment (infrastructures and buildings)

European citizens spend – on average – over **90% of their time indoors** (and even more if we consider mobility aspects where they rely on transport infrastructures), meaning that our health and wellbeing strongly depends on how and with which materials our buildings and civil engineering structures are built, maintained and renovated.

40% of Europe's energy consumption comes from buildings, and they generate 36% of GHG emissions in the EU. With a staggering 97%[4] of the housing stock estimated as being energy inefficient, the building sector is one of the key enablers for achieving low carbon economy goals for 2050. However, the annual rate of home and commercial building renovation (around 0,4 -1,2%[5]) is well under the 3% required to achieve such goals.

With **more than 12 % of its building stock protected due to its cultural and architectural value**, the European built environment also highly contributes to cultural tourism incomes and European identity in a multicultural environment. With the Davos declaration[6] in 2018, world leaders highlighted the importance of *Baukultur* in the European Built Environment.

Infrastructure networks transport people and goods and are fundamental lifelines of today's society. Europe possesses one of the densest and most developed infrastructure networks in the world[7], a huge legacy and accumulated investment inherited from its long history. **Most of these infrastructures were constructed in the period 1960-1970** and were designed for a working life of 50 years. Today, the **investments in infrastructures are far below requirements**. For example, the actual annual investment in transport and logistics infrastructures is only half of the estimated needs[8].



Source: Based on data from BPIE, EC, EIB, Member States

[4] According to a recent study conducted by the Building Performance Institute Europe (BPIE), 97% of European buildings are energy-inefficient, meaning they must be upgraded to comply with the 2050 vision of decarbonisation. This figure is much higher than the 75% previously estimated.

[5] Source : https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings

[6] See "Towards a high-quality Baukultur for Europe", Davos declaration 2018. Definition of *Baukultur* is provided in the glossary.

[7] i.e. total road network of approximately 5 million km in the 28 EU Member States (incl. 60,000 km of motorways), total length of railways lines around 215,000 km (of which 107,500 km), and 41,000 km of navigable inland waterways.

[8] Source: "Investment in infrastructure in the EU", European Parliament, 2018

2. Challenges and drivers for the sector

The construction sector must respond to an evolutive framework that is shaped by societal challenges, by policy and regulations attempting to translate those challenges into concrete frameworks serving the society, and by technology and industry trends that might either be considered as challenges or opportunities.

Research and innovation activities, as they are described in this document, tend to integrate and respond to these different elements in order to bring the construction sector and built environment a step forward.

The next sections briefly introduce the main challenges and drivers that will shape the recommended R&I activities presented further below in this document.

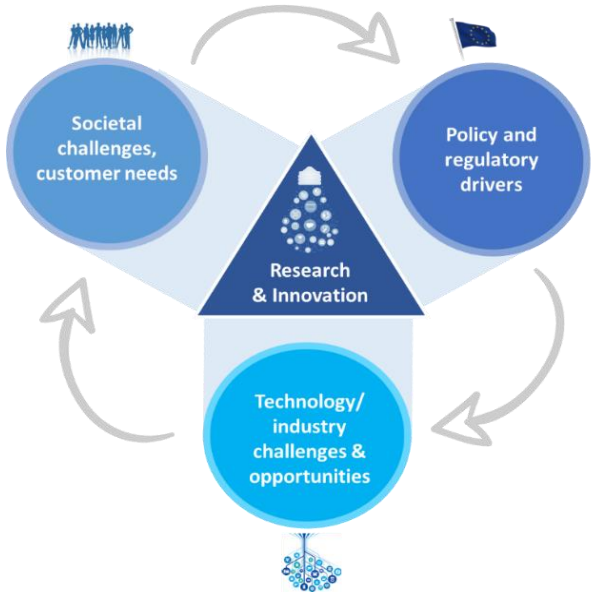


Figure 1: evolutive framework of Research and innovation in construction industry

2.1. Societal challenges and their consequences for the sector

The main identified societal challenges faced by the construction sector are related to **climate change, population ageing and urbanisation:**

- Climate change mitigation policies and the transition towards a climate neutral society, with limited environmental impacts, involves an in-depth transformation of the European industry, and therefore of the construction sector as a key contributor and enabler;
- Europe faces an unprecedented demographic shift, with almost one out of three Europeans being 60 or older[9] in 2060;
- by 2030, 80% of European citizens will live in urban areas.

In order to take up these challenges, the construction industry must initiate and/or pursue profound changes, as described below.

- **Climate change**

For the construction sector, **tackling climate change, as well as other environmental issues** (raw material scarcity, pollution, biodiversity loss, resilience to natural hazards including but not limited to earthquakes and floods, disruptors…), implies to**:**

[9] Source: UN World Population Prospects, 2012 Revisions

- **Rethink the way we design, manufacture, build and maintain** buildings and infrastructures as well as **manage their end of life**, in order to drastically reduce the carbon footprint of the overall construction processes and the consumption of raw materials. This implies to exploit at best all the potentialities of both innovative technologies and nature-based solutions, and to shift from the current 'silo-based' working habits to a fully integrated, **lifecycle-based approach;**
- **Change gears in terms of renovation and integration of renewable energy sources**, so that the way we live in the built environment becomes more sustainable. Going from the current renovation rate below 1% to an average 3% is a major challenge that will require technology cost drops, flexible and performance-based products and services, as well as new financing schemes. Integrating more renewable electricity and the possible electrification of mobility will also require the adaptation and upgrade of infrastructures (ICT requirements, interfaces with electricity network), as well as new approaches fostering local energy uses and district-scale approaches (for instance with local and/or citizen energy communities);
- **Attract, train and retain knowledgeable and skilled workforce**, committed to environmental performance targets, which requires to renew in-depth the educational pathways and tools.

- **Ageing of the European population**

Addressing these challenges requires to:

- **Adapt the existing built environment and design next one** so that the elderly can remain longer independent in their homes and lead healthy and active lives in public spaces and infrastructures. This implies a **major upgrade of the current housing stock as well as infrastructures with a focus on mobility**, with appropriate technical and financing solutions in terms of age-friendly and holistic renovations. Here again, today's low renovation rate turns this required housing stock upgrade into a major challenge.
- Propose new (largely ICT-based) services to support the daily living of older citizens in their homes, public spaces and infrastructures ("**building as a service**");
- This implies to embrace a **citizen-centred approach of the built environment**, including two main dimensions: first, how users are incorporated into the processes of designing space ("design by users" or "co-design"), and second, how users' experiences and existing practices can be used (and shaped) to better inform and manage the built environment operation ("design for users").
- Addressing this challenge also represents **a wider opportunity to deal with the generic issues of inclusiveness (not limited to age) and accessibility**, and how to design and adapt the built environment for maximised performances to this regard.

- **Urbanisation**

Accompanying the urbanisation trend in Europe implies to:

- Contribute to the emblematic European objective of 100 Carbon neutral cities by 2050 (see "climate change" challenge above);
- Provide technical solutions building on data and sensor information (Digital Twins, supervisors, etc.) and contribute to organisational processes that enable the active participation of all citizens in the city assets management (from participative urban planning to inclusive and responsive buildings and public spaces);
- Propose new concepts and designs that foster sustainable behaviours and biodiversity within and around the city (reduced commuting, local supply chains, revegetation, urban food production), to improve the quality of life and climate resilience of urban areas;
- Design, retrofit and upgrade buildings and infrastructures to consolidate cities into resilient hubs with adapted and optimised urban mobility, while adopting a holistic approach (connection

between different types of networks, connection between different cities which also account for rural areas);

- Deploy solutions to ensure the restoration and long-lasting preservation of the Cultural Heritage, its full integration into the citizen's life as a meaningful, liveable and resource-efficient built environment, and leverage its full potential as a driver for urban regeneration and tourism.

2.2. Industrial and technological trends as challenges and opportunities

Some deep technological and industrial trends currently experienced by the construction sector can be considered either as challenges or opportunities for the decade to come. We do not argue here to which extent those trends belong to the former or the latter, but rather try to describe them briefly as an introduction to some of the Research and Innovation priorities described later in this document. We name as main industrial and technological trends: ageing of infrastructures, industrialisation of the construction processes, new materials, and digitalisation.

- **Ageing infrastructures must evolve and adapt to new uses and hazards:**

Most European infrastructures, constructed in the period 1960-1970, are now beyond their theoretical working life, while their use is stretched beyond their initial capacities in load and traffic. In addition, the changes in living and mobility patterns (electrification of transport, integration of autonomous vehicles, integration of renewable energy) as well as increasingly severe natural hazards require existing infrastructures to undergo a major upgrade, involving massive investments. Successfully achieving this refurbishment and new developments implies to:

- Perform well-informed decision making on investment options for infrastructure maintenance and upgrades, by taking benefits of past track records, and by adopting an asset management perspective considering the full life cycle;
- Deploy cost efficient techniques to monitor, maintain, retrofit, upgrade and adapt infrastructures - including the supporting geostructures - according to the new uses and users (electro mobility, sharing options, ageing users…) while minimizing interruptions (e.g. stealth construction sites), and to increase their durability and resilience to climate change and man-made hazards.

- **The industrial (r)evolution is still awaited to strengthen the construction ecosystem:**

With labour productivity growing at around a quarter of the rate in manufacturing sectors (1% vs. 3.6% respectively), the construction sector is the poorest performer in terms of productivity[10]. Improving

[10] The Economist (2017). The construction industry's productivity problem

the sector's competitiveness is *the* key pillar to reinforce the construction industry and to let it embrace the globalization trend of the sector. In a landscape dominated by SMEs, the major challenge is to enable the whole ecosystem to integrate the available new technologies (e.g. automation, artificial intelligence, Building Information Modelling, Internet of Things, advanced materials, robotization, additive manufacturing) and working processes (design, prefabrication, on-site assembly). Transitioning to this *industry 4.0* shall pave the way to higher productivity, quality, and safety in the construction processes together with lower environmental impact, and to increased sustainability, fitness-for-use and resilience in the resulting built environment. This requires to:

- **involve a maximum number of SMEs in this process of integrating new technologies** and practices, i.e. demonstrate to them the added value of changing their practices and investing in new solutions and training – a demonstration in which large contractors will play the leading role, in an Open Innovation fashion;
- Make use of such technologies to **shift from a process-based to a service-based industry** providing **integrated services, within a more integrated value chain;**
- initiate a deep **upskilling in competences of the existing workforce** (about digitalization, environmental performances…), and attract new talents (including scientists) with valorising career perspectives;
- use regulation, standardization and public procurement as tools to support the deployment of innovations at real-life scales.

- **Digitalisation is to be generalised in the construction processes and in the built environment**

Digitalisation is a steppingstone to achieve the above-mentioned industrialisation of the sector ("industry 4.0" applied to the construction sector). For instance, it is estimated that full-scale digitalisation in non-residential construction would lead to annual global cost savings of 13% to 21% in the engineering and construction phases and 10% to 17% in the operations phase[11]. These gains will be enabled by the full deployment of Building Information Management (BIM) and, in the longer term, (dynamic) Digital Twins; by automation and robotics; and more generally by data-based tools and services (which make use of the latest advances in IoT and embedded sensors, cloud computing, massive processing of Big Data, and Artificial Intelligence).

Though, construction is the least digitised sector in the EU, and **digital technologies disrupt the traditional value chain**. Behind a few leaders (the UK, Scandinavia, Germany, France) and some "beginners", many European countries have not yet initiated the digital transition in construction, still waiting for clear demonstrations of its tangible benefits[12]. Taking up the digitalization challenge involves:

- Test and demonstrate which digital technologies provide clear and measurable benefits for which applications and markets, with resulting technology applications that are tailored to SMEs;
- Develop strong digital capabilities within the workforce in order to make the best use of current digital solutions and to rapidly integrate the new ones that will emerge in the next 20 years;
- Set a common and open data framework, requiring significant standardisation efforts, an issue on which large corporate contractors will have to take the lead.

- **New and adaptable materials must be integrated to achieve more resilience, comfort, health, safety, resource efficiency, CO2 neutrality and availability of the built environment**

[11] BCG (2016). Digital in Engineering and Construction https://www.bcg.com/industries/engineered-products-infrastructure/digital-engineering-construction.aspx

[12] See State of BIM adoption across Europe: https://www.e-zigurat.com/blog/en/state-of-bim-adoption-europe/

The permanent advances in material sciences and engineering offer new opportunities to support the performance and resilience of building and infrastructures, the integration of renewable energy sources in the new and existing (including historic) built environment, as well as its comfort and sustainability. One can mention, among others:

- self-healing materials for improved resilience of infrastructures; multifunctional material (e.g. antimicrobial and self-cleaning materials)
- energy efficient, energy harvesting and storage materials (e.g. piezoelectric materials in cement composites) for renewable energy sources in buildings and infrastructures;
- bio-based materials and innovations in wood engineering;
- materials with cooling/heating effects such as hydroceramics and thermoelectrics for inner temperature regulation;
- improved thermal and acoustic insulation materials for energy efficient buildings (e.g. foams and phase change materials);
- in situ enhanced materials that reduce raw material consumption (e.g. environmentally friendly in situ ground improvement techniques that lead to use of less greenfield);
- re-useable materials (e.g. reuse of foundations) and materials based on recycled wastes
- smart materials with self-sensing capacity for damage detection
- advanced materials for lighting technologies (LEDs and OLEDs) or dynamic glazing.

The main challenge is to validate the industrial and economic potential of such low-maturity materials for construction applications. In this context, the prediction of long-term material performance through degradation modelling, based on reliable and complete data sets covering design, material and compound properties, has a key role to play.

2.3. Policy and regulatory drivers

A large range of EU and national policies apply to the built environment and the construction sector:

- **Energy consumption of buildings**

The 2010 **Energy Performance of Buildings Directive (EPBD)** and the 2012 **Energy Efficiency Directive** are the EU's main legislation when it comes to reducing the energy consumption of buildings. The 2018 revised EPBD promotes the use of smart technology in buildings to streamline the existing rules, including among other a **zero-emission building stock target by 2050,** a **smart readiness indicator (SRI)**, the **rollout of e-mobility infrastructure**; and the mobilisation of **public and private financing for renovation** activities to tackle **energy poverty.** According to article 2a, EU countries will have to establish **stronger long-term renovation strategies**, aiming at decarbonising the national building stocks by 2050[13], with indicative milestones for 2030, 2040 and 2050, measurable progress indicators and with a solid financial component (all Member States are obliged to submit their 3rd long-term renovation strategy by 10 March 2020). The revision of the Energy Efficiency Directive from December 2018 set an **energy efficiency target at least 32,5 %, by 2030,** with a possible upward revision clause.

- **Waste management and the circular economy**

Construction and Demolition Waste (CDW) accounts for approximately 25% - 30% of all waste generated in the EU. The Waste Framework Directive (2008/98/EC) aimed at providing a framework

[13] To contribute to the 2050 goal of reducing greenhouse gas emissions in the Union by 80-95 % compared to 1990

towards a European recycling society with high resource efficiency, setting **by 2020 a target of minimum of 70% (by weight)** of non-hazardous construction and demolition waste to be prepared for re-use, recycled or undergo other material recovery. In 2015, the European Commission also adopted an ambitious Circular Economy Action Plan, which includes measures that will help stimulate Europe's transition towards a circular economy.

- **Strategic Energy Technology Plan**

The European Strategic Energy Technology Plan (SET-Plan) aims to accelerate the development and deployment of low-carbon technologies. In September 2015, the European Commission adopted a Communication for an Integrated Strategic Energy Technology Plan (C(2015) 6317 final), identifying ten priority actions to accelerate the energy system transformation. Of relevance for the present SRIA: Action 3: Create technologies and services for smart homes that provide smart solutions to energy consumers; and 5 - Develop new materials and technologies for, and the market uptake of, energy efficiency solutions for buildings.

- **Paris Agreement**

The Paris Agreement on Climate change sets a common legally binding agreement to hold global warming well below 2°C with aspiration to achieve 1.5°C, integrated with frameworks for action on resilience and adaptation. UNFCCC Conference of the Parties (COP21) summit in 2015 also saw a growing awareness of the carbon-saving value of retrofitting existing building stock and put an emphasis on the adoption of novel building materials, designs and technologies.

- **Policy framework for climate neutral cities**

The Pathway towards **Positive Energy Districts** (defined in SET Plan Action 3.2 Implementation Plan) targets at least 100 Positive Energy Districts (PED) deployed in Europe and synergistically connected to the energy system by 2025. The EC **Mission for Climate neutral and smart cities by 2030**[14] **defines that,** by 2030, 100 cities have reached a net zero greenhouse-gas-emission balance.

- **Policy framework for decarbonised transport and related infrastructures**

The Roadmap to a Single European Transport Area ("Towards a competitive and resource efficient transport system") released by the EC in 2011 sets 10 goals to reach a reduction of at least 60% of GHGs by 2050 in the transport sector (compared to 1990), relying among others on cleaner urban transports and modal shifts, and the required adaptation of the related infrastructures.

[14] Mazzucato M. (2018) Mission-Oriented Research & Innovation in the European Union - A problem-solving approach to fuel innovation-led growth

3. ECTP long term vision and 2030 objectives

3.1. A participative and consultative SRIA elaboration process

The elaboration of the SRIA was structured along the following the process, illustrated in Figure 1:

- Definition of an integrated and shared **long-term vision**, and of **goals** underlying this vision,
- Definition of **mid-term objectives** and associated quantified **targets** to meet these goals,
- Identification of **barriers** to overcome and **drivers** that can act as points of leverage,
- Proposition of **R&I topics** to overcome the barriers, and clustered in **R&I priority areas**.

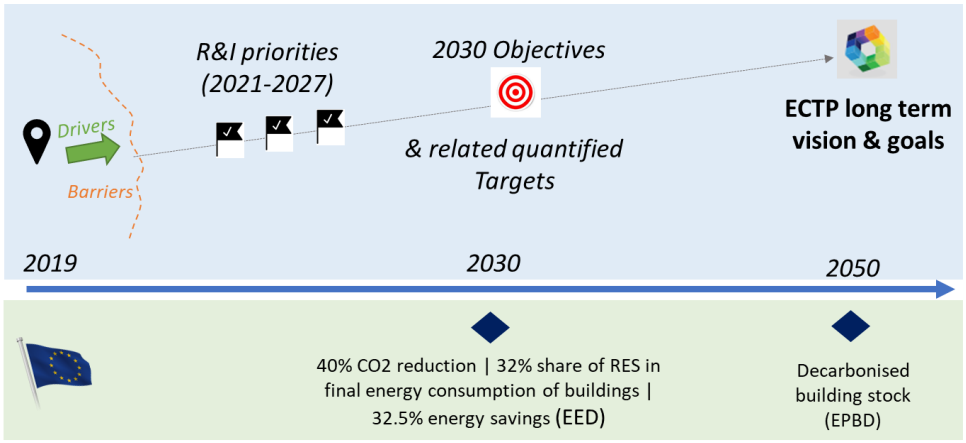


Figure 1 : Structure of the SRIA and phasing with main EC regulatory targets

To ensure that the SRIA adequately reflects the ambitions of all involved parties, a **co-creation process** was implemented with the stakeholders from within and outside ECTP from March to October 2019. It combined a set of bilateral interviews with ECTP member and other associations, two collaborative workshops followed by an open consultation, and concluded by a final review process.

3.2. ECTP vision 2050

The **long-term vision of the ECTP** for both the built environment and related industry sectors is formalised as follows:

A climate neutral built environment enabling the well-being of all EU citizens, provided by a circular, digitalised and prosperous construction ecosystem.

3.3. Three major goals towards 2050

The above described long term vision is translated into three interconnected goals to the time horizon 2050, summarised in Figure 2 and described in the text that follows:

Figure 2 : Goals for the built environment and the construction sector

- ***Goal 1: Clean built environment and cities***. **The 2050 ambition is to reach a built environment that is CO2 neutral, resource efficient and high performing over its whole life cycle**.

By 2050, the built environment fully integrates renewable energy sources while reaching high energy efficiency, and the construction industry has fully transformed to resource efficient, circular industrial and construction processes, including flexible and LCA-based design. This goal embraces an integrated vision of climate-neutral and resilient cities as a network of well-connected hubs, with a specific focus on the district scale efficiency (symbiosis in energy uses and production, shared assets) including the integration of new mobility patterns and the necessary adaptation of infrastructure to this end.

- ***Goal 2: Built for and with the people***. **The 2050 perspective is to provide a service-oriented built environment that enables every European to live better and more sustainably.**

By 2050, the built environment is built *with* the people thanks to generalised participative processes that allow buildings and infrastructures to be designed and operated in higher adequacy with citizen needs. Beyond the planning and design phases, such participative processes allow the active and beneficial involvement of citizens in the operation, monitoring and management of buildings and assets, thanks to tailored education and awareness raising. The built environment is healthy, comfortable, safe, fully inclusive, and promotes sustainable behaviours and sobriety of use. It provides continuity of service between private and public spaces, between one city, its suburbs and surrounding rural areas, and the next city. Buildings and infrastructures are built in a flexible and responsive approach allowing the fast adaptation to new needs, uses, or threats, and facilitating behavioural change towards more sustainable ways of living.

- ***Goal 3: Prosperous construction ecosystem.*** **The goal for 2050 is to make Europe the worldwide reference in sustainable and digitalised construction ecosystem.**

By prosperous eco-system is meant a sector that is attractive and responsible, competing on a global scale thanks to sustainable industrialization and digitalization, and delivering a more flexible and

resilient data driven built environment. By 2050, the construction sector has successfully transitioned to a fully digitalised sector allowing mass customization, and the industry is able to integrate any new digital technology rapidly and efficiently, from large companies to the smallest SMEs. Manufacturing has rationalised its efficiency and sustainability; productivity and quality standards in the construction processes are completely renewed; buildings and infrastructures are safer, more durable and cost-effective in their maintenance and upgrade. The construction ecosystem is closely intertwined to other economic sectors, allowing to provide combined service offers to citizens that enable seamless living from personal to public spaces.

3.4. Four objectives by 2030

For each 2050 goal, a concrete objective for the time horizon 2030 is set, addressing the main challenges introduced above. A fourth, cross-cutting objective focusing on *digitalisation* is added, as a key *enabler* and major success factor for the other 3 objectives. These 2030 milestones are synthesised in the next diagram and briefly presented in the following paragraphs.

Figure 3 : Objectives 2030 for the built environment and the construction sector

1: Clean built environment and cities. **The 2030 objective is, very pragmatically, to reach the environmental and energy objectives 2030 set by the EU,** in its energy framework and related key targets[15] as well as the EU circular economy action plan. This will be met thanks to affordable offers for new constructions and renovation; innovative urban design concepts enabling more sustainable living and mobility patterns; positive energy districts and communities (including historical centres) that are fully integrated in the energy system as active elements; and circularity of resources (including urban mining[16] and urban food production).

[15] 40% cuts in greenhouse gas emissions (from 1990 levels), 32% share for renewable energy, 32.5% improvement in energy efficiency.

[16] Urban mining (UM) concerns all the activities and processes of reclaiming compounds, energy, and elements from products, buildings, and waste generated from urban catabolism (Baccini & Brunner, 2012)

2: Built for and with the people. **The 2030 objective is that Europe becomes a world leader in age-friendly, inclusive, well-connected spaces; participative planning & design; and valorisation of Cultural Heritage.**

To establish a built environment that allows any European citizen to live better and more sustainably in 2050, the ambition by 2030 is to take a real advance in the adaptation of buildings and infrastructure to the needs of an ageing population. Urban planning and building design must become fully participative processes in order to integrate at best the user needs while complying with climate and environmental constraints. Citizen involvement shall also become a reference to optimise the operation of built assets and valorise urban green spaces. The built environment must integrate all knowledge and innovations that can contribute to improve the indoor and outdoor environment quality, and the responsiveness of buildings and mobility infrastructures in view of increased comfort and customised services. New technologies, in particular digital ones, shall be used to increase the accessibility and inclusiveness of the built assets, and take maximum benefit of the cultural heritage which contributes to regenerating depopulated areas, developing tourism, and liaising between social communities. Finally, new business models and financing mechanisms must be invented to make tomorrow's improved built environment within the reach of all European citizens.

3: Prosperous ecosystem. **The 2030 objective is to reach a 20% productivity increase** through upgraded and innovative industrialised construction processes, cross-sector partnerships and skilled workforce. This gain will result from the integration and rationalisation of new materials, technologies, new designs and techniques in the manufacturing and construction processes that will trigger drastic cost reductions; a real step forward in the workforce qualification regarding new technologies and performance-based commitments; and a paradigm shift towards asset management (whole life cycle approach) that will value at best predictive maintenance and resilience of buildings and infrastructures. This transition will require 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).

4: Digitalisation: **The 2030 objective is that all construction companies, including SMEs, in Europe adopt digital tools in a common and open framework, to deliver smart-ready buildings and infrastructures**

Digitalisation of the construction sector is increasingly recognised as a game changer for the sector. With BIM as a front-runner, all key enabling digital technologies and IT infrastructures need to be integrated in a dynamic way to support the achievement of the other goals. The inclusiveness of this transformation (i.e. embark all the actors of the construction ecosystem, in particular SMEs, and be accepted by all EU citizens) is a prerequisite to ensure the success of the digitalization and maximise its positive impact for the value chain and the EU citizens as a whole. The **2030 objective** therefore focuses in the progressive **uptake of digital tools by construction companies, in particular SMEs**. The digitalisation of the construction sector will also contribute to a clean energy transition and to a more sustainable living: thanks to digital technologies and data economy, buildings and infrastructures will become an active part of the energy system (see objective 1). Data storage, protection and accessibility is another focal point which needs to be addressed carefully.

4. Overview of R&I priorities and related budget requirements

4.1. Research and innovation priorities

The Research and Innovation priorities address the R&I needs identified by the ECTP members, in cooperation with other associations related to the construction sector (see first page of this report on *Contributors*), necessary to overcome the current barriers and meet the 2030 objectives and their associated targets.

The next table introduces an overview of the R&I priorities structured according to the above defined four objectives 2030, then further detailed in the following sections.

Research and Innovation priority areas, per objective

Objective	*R&I priorities*
Clean built environment and cities	1.1 Energy renovation of buildings and upgrading of infrastructures 1.2 Positive energy building blocks & districts, integrated with the urban networks 1.3 Life Cycle Approach and Circular Economy
Built for and with the people	2.1 Participative and dynamic built environment 2.2 Inclusive and affordable built environment 2.3 Healthy and comfortable built environment 2.4 Living cultural and historical built environment
Prosperous construction ecosystem	3.1 Cleaner, faster, safer and more cost-effective construction, retrofitting & commissioning processes 3.2 Improved resilience and adaptability of the built environment 3.3 New contractual processes and partnerships for the construction sector 3.4 Educational tools increasing the attractiveness and skills of the industry's careers
Digitalisation	4.1 Smart operation and maintenance of buildings & infrastructures 4.2 BIM & Digital Twins for value chain integration, with focus on SMEs 4.3 Data privacy and security 4.4 Better integration of the built environment with the urban space and mobility

Figure 4 : R&I priorities of the ECTP SRIA

The four objectives are highly interdependent in many aspects, and consequently the R&I priority areas often overlap across two, three or all goals. For instance, accelerating the renovation of the existing

building stock to decarbonise the built environment requires developing attractive offers that allow the market to invest in confidence. These offers can only be developed if the construction sector is competitive with more cost-effective retrofitting processes and need to be user-centred to facilitate their uptake. Digitalisation acts here as an essential facilitator.
Business models, that are also cross-cutting topics, have been clustered under the "Built with and for the people" goal.

For the sake of clarity, the next figure shows how the "Digitalisation pillar" contributes to the other three objectives.

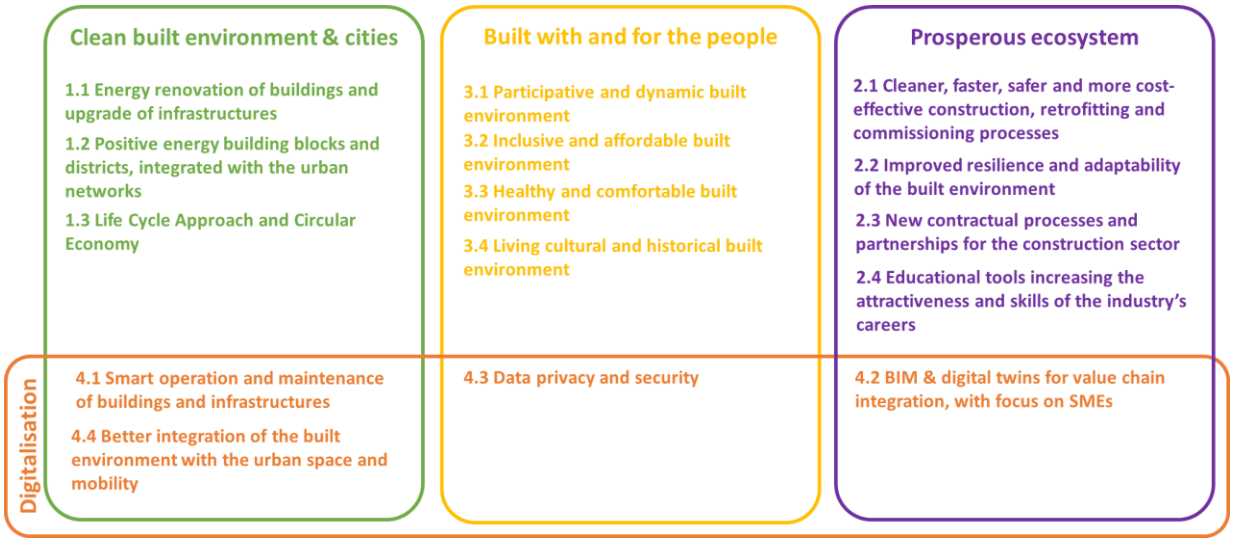


Figure 5 : Cross cutting dimension of the Digitalisation with other three objectives

4.2. Budget estimates

In order to propose an estimate of the required EC funding necessary to implement the actions detailed in this R&I Agenda, two complementary approaches were followed:

- A "bottom up" approach to assess the budget needs at each priority level, relying on the collective intelligence of ECTP members;
- a "top down" approach to cross check those values with more macro-economic figures regarding R&D and innovation investments, using data from the EU Innovation Scoreboard, Eurostat, the construction industry, H2020 programme and PPPs, and the draft Horizon Europe budget.

The proposed breakdown of budget required per R&I priority area (in percentage) was obtained as an average of the respective figures provided by the contributing ECTP members. The individual views collected were fairly in line and the proposed figures reflect a consensus.

As for **the overall EC funding envelope required to contribute to the present SRIA**, an amount ranging between 1640 and 1970 M€ over the full Horizon Europe period is estimated.

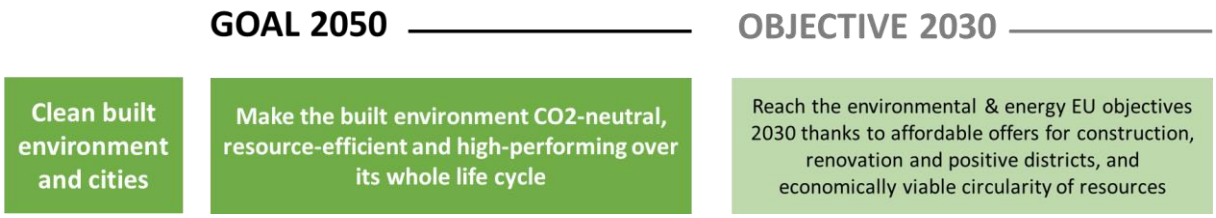
The main assumptions used to build this estimate are presented in annex 3.

	R&I priorities	Breakdown of total EC funding required as contribution to SRIA	Range in M€ over 2021-2027 period
Clean built environment and cities		30%	492 – 590 M€
	1.1 Energy renovation of buildings and upgrading of infrastructures	16 %	262 - 315 M€
	1.2 Positive energy building blocks & districts, integrated with the urban networks	5 %	82 -98 M€
	1.3 Life Cycle Approach and Circular Economy	9 %	148 -177 M€
Built for and with the people		20%	328 -394 M€
	2.1 Participative and dynamic built environment	5 %	82-98 M€
	2.2 Inclusive and affordable built environment	5 %	82-98 M€
	2.3 Healthy and comfortable built environment	5 %	82-98 M€
	2.4 Living cultural and historical built environment	5 %	82-98 M€
Prosperous construction ecosystem		25%	410 – 492 M€
	3.1 Cleaner, faster, safer and more cost-effective construction, retrofitting & commissioning processes	9 %	148 -177 M€
	3.2 Improved resilience and adaptability of the built environment	8 %	131 -157 M€
	3.3 New contractual processes and partnerships for the construction sector	5 %	82 -98 M€
	3.4 Educational tools increasing the attractiveness and skills of the industry's careers	3 %	49 - 59 M€
Digitalisation		25%	410 – 492 M€
	4.1 Smart operation and maintenance of buildings & infrastructures	9 %	148 - 177 M€
	4.2 BIM & Digital Twins for value chain integration, with focus on SMEs	8 %	131 - 157 M€
	4.3 Data privacy and security	4 %	66 -79 M€
	4.4 Better integration of the built environment with the urban space and mobility	4 %	66 - 79 M€

Figure 6 : Overview of R&I priorities with related EC funding estimate for Horizon Europe

5. R&I priorities for objective “Clean Built environment and cities”

The next figure reminds the Goal set by 2050 for a clean built environment, and the related objective defined for 2030.



5.1. Rationale: barriers and drivers

Major barriers remain to be addressed on the pathway to a clean built environment and carbon-neutral cities.

- Barriers to the acceleration of the energy renovation of the existing building stock: It is widely agreed that most of these barriers are non-technical. They include for instance market failures, lack of information and of stakeholders’ engagement, difficulties to access capital for building owners, lack of trust and fear of disruption, cultural conservation.
- Barriers to the upgrading of infrastructures due to the high impact of disruption times caused by renovation works in critical transport hubs, combined with socio-economic factors related to decision-making on the related investments.
- Barriers to the development of positive energy blocks and districts. During H2020 a variety of projects were launched to develop technical solutions for the construction of zero and positive energy buildings, the implementation of Demand Response at building block scale, better integration of renewables and sharing of energy between buildings, and for a better integration with mobility. However technical barriers remain – in particular in relation to integration, interoperability and industrialisation of solutions, as well as non-technical ones (including business models and financing, market acceptance). All these barriers are exacerbated for historical buildings, centres and districts.
- Barriers to the full engagement in the circular economy. They include the poor confidence in construction and demolition waste quality, low economic attractivity (and highly variable depending on the Member States), user reluctance and, as a consequence, the lack of demand for recycled CDW in general construction as observed in most EU countries and limitations imposed in current standards. Clear and harmonised financial instruments (based on tax and incentives schemes) that make CDW-derived materials more affordable than ‘virgin’ ones are missing. The implementation of a systemic Life Cycle Approach, and in particular LCA-based decision-support tools, is hindered by the absence of a common and open framework (data, methods) for the whole construction sector.
- Barriers to implement industrial symbiosis strategies between construction and other industries and to develop new construction materials using other industries waste, as for

example the lack of cross-sectoral initiatives on the matter or the lack of research on material flows along different value chains.

On the other hand, regulatory, legal and market drivers are compelling the sector to change:

- Regulatory drivers are related to the implementation by the Member States of the Clean Energy Package, and more particularly of the revised EPBD (and associated national roadmaps) and EED, and the Circular Economy Action Plan. The revision of the Electricity Market Directive (with the introduction of Citizens Energy Communities) is likely to bring completely new models.
- At national level, new rules in public procurement (Green Public Procurements - GPPs) and tax incentives for ecoproducts also provide a strong impulse for change (for instance UK, Netherlands, Denmark, Finland and Norway are requiring the use of BIM in public procurements).
- Green building labels (e.g. BREEAM, DGNB) are promoting the use of responsibly sourced and recycled materials, both for buildings and the surrounding infrastructure.
- Cities themselves are a driving force for the decarbonisation of the built environment and the implementation of a holistic approach.

5.2. Targets 2030 and related R&I priorities and topics

The following targets are defined to measure the achievement of the 2030 objective.

TARGETS 2030

- □ 3% annual renovation rate in Europe for buildings and infrastructures
- □ Align with EU 2030 climate and energy targets: 40% CO2 reduction (vs 1990 levels), 32% share of RES in final energy consumption of buildings, 32.5% energy savings
- □ Contribute to achieving EU target on 100 carbon neutral cities
- □ 80% reusable or recyclable materials for new buildings and infrastructures, and for renovation components

The next table provides a synthetic view on the R&I priorities and related topics needed to overcome the above-mentioned barriers, with an indication on timeline, type of activities required, and nature of expected impact. The R&I priorities and topics are then described in the following sections, with a reminder of the related Targets 2030.

Table 1 : R&I priorities and topics for objective "Clean built environment and cities"

R&I priorities and topics	2020-2024	2024-2027	2027-2030	Nature of major impact
1.1 Energy renovation of buildings and upgrading of infrastructures				
Cost-effective multi-functional and/or prefabricated retrofitting technological packages, integrating RES	*Integration/ Demo*			€ 🍃
Certified sustainable and durable construction materials, including re-used and recycled materials	*R&D/ Demo/ Certification*			🍃
Optimal solutions to adapt existing infrastructures to new transport patterns	*Integration/ Demo/ Scaling up*			👥
Green procurements and new business models for renovation supported by decision-making tools	*Demo/ Scaling up*			€
1.2 Positive energy building blocks and districts, integrated with the urban networks				
Smart-grid ready and smart-network ready buildings, acting as active utility nodes	*R&D/ Integration/ Demo*			👥 🍃
Interoperable components for positive energy blocks and districts, including a better integration of local renewables	*R&D/ Integration/ Demo*			🍃
Multi-modal transport hubs and urban mobility infrastructures	*R&D/ Integration/ Demo*			👥
Uptake of performance contracts	*Demo/ Scaling up*			€
1.3 Life Cycle Approach and Circular Economy				
Integration of construction and demolition waste in new constructions and industrial symbiosis		*R&D/ Demo/ Business models*		🍃
More sustainable materials with reduced embodied energy and high performance to reduce the life cycle cost	*R&D/ Integration/ Demo*			🍃
Tools to facilitate the life cycle-based approach	*R&D/ Demo/ Scaling up*			€
New approaches to circular economy and nature-based solutions, including revegetation and urban food production		*R&D/ Demo*		🍃

Legend: 👥 **Societal impact** € **Economic impact** 🍃 **Environmental impact**

Definitions of these impacts are provided in the Glossary of page 3-4.

Abbreviations used to describe the type of R&I activities are defined in page 5.

5.3. R&I 1.1 Energy renovation of buildings and upgrade of infrastructures

Target 2030
- 3% annual renovation rate in Europe for buildings and infrastructures

Highly performant and cost-effective integrated packages for the deep renovation of any types of buildings including historical ones need to be demonstrated, industrialised and rolled out. They shall combine more sustainable components and materials (including biobased materials and nature-based solutions) with user-centred business models. Beyond space and water heating, these solutions should account for the consequences of climate change (warming in particular) and address summer comfort and heat islands issues. Deep renovation solutions must as well include an analysis of resilience of the renovated building/infrastructure against major disruptive events, such as flooding and/or other climate-driven events and/or earthquakes. New solutions for the renewal and adaptation of infrastructures - including the supporting geostructures - to new mobility needs are also required. To support the market uptake of these solutions, different framework measures such as decision-support tools and green procurements must be successfully implemented.

R&I topics
- Cost-effective multi-functional and/or prefabricated retrofitting technological packages, integrating RES - Certified sustainable and durable construction materials, including eco-materials, in situ enhanced, re-used and recycled materials as well as non-toxic composition certification. - Optimal solutions to adapt existing infrastructures to new transport patterns - Green procurements and labels for built environment (building & infrastructure surrounding) and new business models for renovation, supported by decision-making tools (enabling for instance to make informed decision between demolition and renovation)

5.4. R&I 1.2 Positive energy building blocks and districts, integrated with the urban networks

Target 2030
- Align with EU 2030 climate and energy targets: 40% CO2 reduction (compared to 1990 levels), 32% share of RES in final energy consumption of buildings, 32.5% energy savings - Contribute to achieving EU target on 100 carbon neutral cities

In parallel to renovating the existing built environment, it is critical to ensure that the new constructions (around 1% of the building stock per year) are more and more efficient, with a zero-emission target. Reaching the target of climate neutrality – even beyond with positive energy – 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. Considering the district scale enables a better integration of buildings with the urban networks, in particular energy (smart grid ready buildings) and mobility (e.g. provision of charging outlets, vehicle to grid as energy storage). Topics such as heat islands (and related issues of heat

rejection by the warming/cooling systems) or the creation of green spaces and corridors for biodiversity, also need to be tackled at the scale of the building block / district.

R&I topics
- Smart-grid ready and smart-network ready buildings, acting as active utility nodes - Interoperable components and sustainable materials for positive energy blocks and districts (including historical ones), including a better integration of local renewables and technical solutions to tackle heat islands - Multi-modal transport hubs and urban mobility infrastructures - Uptake of performance contracts, from design to operation, including commissioning

5.5. R&I 1.3 Life Cycle Approach and Circular Economy

Target 2030
- 80% reusable or recyclable materials for new buildings and infrastructures and for renovation components

The built environment generates CO2 emissions and environmental impacts (including biodiversity loss) over its whole life cycle, not only during the construction and operation stages. Impacts from "cradle to grave" (and even "cradle to cradle") must be accounted for, from the extraction of the raw materials to the end of life and re-use.

A Life Cycle Approach should systematically be implemented in order to reduce the environmental impact of any construction project, throughout all its phases. To that end, methods and tools to perform Life Cycle analyses in construction projects should be both reliable and replicable. Issues to be considered include, among others, the impact of design on future energy consumption, the embodied energy of material used, materials durability and reuse (e.g. "circular by design"). Urban mining for instance should become a key component of the supply chain. Solutions for the revegetation, urban food production, water reuse and the provision of ecosystem services by buildings and infrastructure should be integrated, contributing to climate resilient, re-natured cities. Environmental impacts such as noise, vibrations and air quality of future ground and underground transportation infrastructures should also be considered.

R&I topics
- Integration of construction and demolition waste in new and existing (including historical ones) constructions and industrial symbiosis - More sustainable materials (and less plastics) with reduced embodied energy and high performance to reduce the life cycle cost - Tools to facilitate the life cycle-based approach, from policy and regulatory framework to data sharing and standards - New approaches to circular economy and nature-based solutions, including revegetation and urban food production

6. R&I priority for objective: “Built for and with the people”

The next figure reminds the Goal set by 2050 for a Built environment for and with the people, and the related objective defined for 2030.

6.1. Rationale: barriers and drivers

Some key barriers remain to be addressed in order to reach a built environment that is fully participative, inclusive, healthy and comfortable, as well as affordable:

- There is a clear lack of financing mechanism for renovation projects, which makes renovation out of the reach for many citizens, and in particular not attractive to ageing people although they might need adaptations of their environment to their new needs;
- Though some strategies for regeneration of depopulated areas have been identified, there is, still, a lack of funding and political will to implement those recommendations;
- Building and infrastructure design is still driven by a “techno push” paradigm, top-down mindsets that do not place the users and citizens at the centre of the process;
- So far, the return on experience regarding the use of digital technologies to develop accessibility and inclusiveness of certain sites (e.g. virtual or augmented reality) or participative processes (e.g. apps and platforms for urban planning and design) is quite limited, and the related benefits difficult to assess and valorise;
- European cultural heritage is endangered, as it is still considered as an expense instead of a resource. Climate change and scarce maintenance are hindering its proper conservation and promotion;
- The “silo approach” between the different transport sectors (different stakeholders projecting the future of each transport mode in an uncoordinated way), and between the different phases of building/infrastructure life cycles (different stakeholders involved in design vs build vs operation), prevent the design and operation of asset to be optimised according to citizen needs and feedback.

On the other side, some societal and technological trends will support the shift towards a more citizen-centred built environment:

- The ageing of the overall European population creates high-potential market opportunities, to be leveraged by segment-specific, innovative business models and partnerships;

- Digitalisation will be a key enabler to make the built environment responsive to user needs (IoT, sensors) and able to provide tailored services – as long as privacy issues can be handled respectfully. It will as well enable to process user behaviour data to improve building/infrastructure design and operation.
- Some work is already initiated by the EC on measuring the *smart readiness* of buildings in view of raising awareness about the benefits of ICT in buildings and motivate building owners to accelerate their related investments.

6.2. Targets 2030 and related R&I priorities and topics

The following targets are defined to measure the achievement of the 2030 objective.

TARGETS 2030

- ☐ KPIs to measure the implementation of participative approaches in urban planning and design and 15% increase of participative processes in urban planning
- ☐ Availability in all EU member states of a common evaluation/ certification framework for age-friendliness performances of buildings
- ☐ 50% of building renovations consider 'age-friendliness' criteria and 75% of new build are age-friendly
- ☐ Availability in all EU member states of a common evaluation/ certification framework for healthiness and wellbeing of the built environment
- ☐ Zero disruption (renovate while in use)
- ☐ Zero loss of cultural heritage
- ☐ 50% increase in urban food production

The next table provides a synthetic view on the R&I priorities and related topics, with an indication on timeline, type of activities required, and nature of expected impact. The R&I priorities and topics are then described in the following sections, with a reminder of the related Targets 2030.

Table 2: R&I priorities and topics for objective "Built for and with the people"

R&I priorities and topics	2020-2024	2024-2027	2027-2030	Nature of major impact
2.1 Participative and dynamic built environment				
Solutions to foster dynamic and participative urban planning, down to building level	*R&D/ Demo/ Scaling up*			👥
Interactive management of city assets	*R&D/ Demo*			👥
Solutions for the regeneration of urban and rural areas		*R&D/ Demo*		👥
2.2 Inclusive and affordable built environment				
New designs of buildings, infrastructures, multimodal hubs and public spaces for accessibility & inclusiveness	*R&D/ Demo*			👥
Solutions for the ageing population, including new services from home	*R&D/ Demo/ Scaling up*			👥
Financing schemes and business models for holistic renovation services (energy, accessibility, comfort)	*Business models/ Demo/ Scaling up*			€
2.3 Healthy and comfortable built environment				
Solutions for healthier indoor/ outdoor environment from building to city scale	*R&D/ Integration/ Demo*			👥
Solutions for smart and responsive buildings exploiting an improved knowledge of user experience (Building as a service)		*R&D/ Integration/ Demo*		👥
Low-disruptive construction and retrofitting processes	*R&D/ Integration/ Demo*			€
2.4 Living cultural and historical built environment				
Solutions for a more open, accessible and inclusive cultural heritage	*R&D/ Integration/ Demo*			👥
Solutions for a low carbon, resource efficient and resilient cultural heritage, from prevention and monitoring to maintenance and retrofit	*R&D/ Integration/ Demo*			🍃
Sustainable tourism strategies preserving cultural assets		*Demo/ Scaling up*		👥 €

Legend: 👥 **Societal impact** € **Economic impact** 🍃 **Environmental impact**

Definitions of these impacts are provided in the Glossary of page 3-4.

Abbreviations used to describe the type of R&I activities are defined in page 5.

6.3. R&I 2.1: Participative and dynamic[17] built environment

Target 2030
- KPIs to measure the implementation of participative approaches in urban planning and design processes - 15% increase of participative processes in urban planning

The knowledge gained from social sciences regarding citizen involvement in design and planning, combined with digital solutions allowing interactivity and data gathering and analysis, must be integrated and consolidated in order to roll out participative processes for urban planning, and building & infrastructure design. Participative process should also apply to the operation and maintenance of buildings, with the development and demonstration of solutions using citizen feedback to improve the efficiency of use, comfort, governance and preservation of the assets. Also, initiatives to encourage and facilitate the renovation process (e.g. one stop shops) should be scaled up.

The strategies already identified to foster urban and rural regeneration in full compliance with cultural heritage preservation must be applied at larger scale to collect valuable return on experience.

R&I topics
- Solutions to foster dynamic and participative urban planning, down to building level - Interactive operation and management of city assets - Solutions for the regeneration of urban (including historical centers) and rural areas

6.1. R&I 2.2: Inclusive and affordable built environment

Target 2030
- Availability in all EU member states of a common Evaluation/ certification framework for age-friendliness performances of buildings - 50% of building renovations consider 'age-friendliness' criteria and 75% of new build are age-friendly

The new requirements for a globally ageing population and the need to address energy poverty are at the centre of this R&I priority. ICT based solutions and services as well as building and public space designs must be developed and tested to allow ageing citizens to live longer and autonomously in their homes and communities (accessible and inclusive transportation and spaces for community interaction). The concept also includes all populations who can suffer from a lack of accessibility and inclusiveness of the built assets (children, elderly, disabled, low income, etc.), and to the built environment as a whole, Cultural Heritage included. A common framework for evaluating inclusiveness and accessibility should be deployed, starting with indicators on age-friendliness. Their integration into local/national regulatory environments should be monitored and assessed.

[17] *Dynamic built environment* is meant as a built environment that is designed, built and operated within a dynamic, interactive relationship with citizens.

New services and financing mechanisms must be invented and tested in order to increase the renovation rates and make such projects economically accessible to all citizens. To that end, a holistic approach to renovation must be developed, addressing at once energy, accessibility and comfort. This will involve partnering with other sectors (banking, insurance, safety, ICT) to provide packaged, "all in one" services, that cover not only the renovation phase, but the everyday life as well, for instance with new services related to monitoring and support to ageing citizens, that respect privacy.

R&I topics
- New designs of buildings, infrastructures, multimodal hubs and public spaces for accessibility and inclusiveness - Solutions for the ageing population, including new services "from home" - Financing schemes and business models for holistic renovation services (energy, accessibility, comfort), including incentive alignment (e.g. tenant vs owner)

6.2. R&I 2.3: Healthy and comfortable built environment

Target 2030
- Availability in all EU member states of a common evaluation/ certification framework for healthiness and wellbeing of the built environment - 50% increase in urban food production - Zero disruption: renovate while in use

This priority is focused on air quality, comfort (smart heating and cooling) and seamless use of the built environment. New technologies, nature-based solutions and bio-sourced materials must demonstrate their technical and economic feasibility as enabler of an improved indoor and outdoor environment, covering the dimensions of air quality, safety and comfort (including acoustics, vibrations, aero-hygro-thermal comfort, etc). ICT-based solutions must be scaled up to allow for a smart, responsive building that can adjust to user needs in real time and learn from its occupants' behaviours. Integrated solutions for revegetation as well as participative management of green urban spaces should be developed and implemented to support biodiversity and the battle against urban heat islands. Concepts and solutions for urban food production should also be further explored.

Low-disruptive construction and retrofitting processes must be scaled up in order to reduce the interruption time for infrastructures and public spaces, and citizen's discomfort in case of housing renovation.

R&I topics
- Solutions for healthier indoor and outdoor environment (air quality, safety, comfort, revegetation, local food production) from building to city scale - Solutions for smart and responsive buildings exploiting an improved knowledge of user experience (Building as a service) - Low-disruptive construction and retrofitting processes

6.3. R&I 2.4: Living cultural and historical built environment

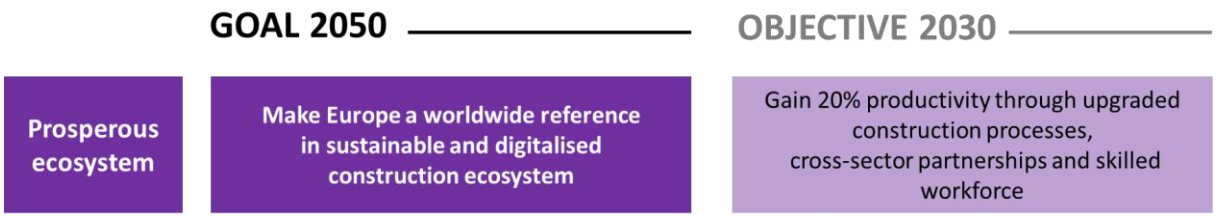
Target 2030
- Zero loss of cultural heritage

A holistic technical and methodological framework needs to be developed for Cultural Heritage maintenance, building bridges of understanding and compatibility between the existing building stock with cultural value, and the current requirements of safety, habitability, environmental sustainability, support for the elderly, preservation of identity and tolerance. Cultural Heritage is no longer about restoration of symbolic (iconic) heritage or the importance of a single asset: the ancient concept of considering monuments should be enlarged to include historic buildings and cities, cultural landscapes, modern architecture and other elements responsible of our European identity. They must become an essential part of the living environment and the fulfilment of societal needs in a changing world, where Cultural Heritage should be adapted to reach the citizen's requirements, in continuous evolution, while preserving its authenticity and integrity.

R&I topics
- Solutions for a more open, accessible and inclusive cultural heritage - Solutions for a low carbon, resource efficient and resilient cultural heritage, from prevention and monitoring to maintenance and retrofit - Sustainable tourism strategies compatible with conservation of cultural assets *(NB: the topic of urban/rural regeneration, in which Cultural Heritage plays a key role, is tackled in R&I priority 3.1)*

7. R&I priorities for objective “Prosperous construction ecosystem”

The next figure reminds the Goal set by 2050 for a prosperous construction ecosystem, and the related objective defined for 2030.



7.1. Rationale: barriers and drivers

Major barriers remain to be addressed on the pathway to a fully industrialised construction ecosystem that ambitions to compete worldwide:

- Many steps in construction are still hand-crafted processes that lack automation and mass customization, a major barrier to cost reduction;
- Even more, the unicity of each construction project and site is a concrete limitation to any optimisation ambitions. More generally, optimisation remains an issue from the design to the demolition phase (lack of common -and open- framework for data, design, testing, etc.)
- In many countries, public procurement rules today are still very constrained to selection of the lowest bid and leave too little room for the deployment of innovations, thus slowing the rate of return on experience and learning curves;
- The current ‘silo’ approach between the different phases of the building life cycle and their respective -very fragmented- stakeholders prevents a life cycle approach which could bring many economic benefits; in the same idea, the lack of coordination between transport sectors (road, railway, waterways) and how they design their respective futures hinders the optimised design and upgrade of infrastructures;
- A deep lack of digital qualification in the workforce impedes the take up of digital technologies in the sector. In addition, data privacy and cybersecurity are pending issues, and there is yet no common data framework for the sector;
- Decision making regarding heavy, critical investments (in particular in infrastructures) is performed with limited information and with close to no capitalization of experience.

On the other side, some strong technological drivers will support the sector’s revolution:

- Digitalisation (AI, Data analytics), automation and robotics are major assets to drive the industrialisation process, from material conception to manufacturing, from building and infrastructure design to investment making, commissioning and asset management. Integrating those technologies paves the way to more resource efficiency, flexibility in design and manufacturing, and productivity gains.

- The current innovations in material sciences pave the way to more resilience, safety, sustainability, and responsiveness for the built environment.

In addition, the EU circular economy package shall be regarded as a great opportunity for the industry to rationalise its use of resources.

7.2. Targets 2030 and related R&I priorities and topics

The following targets are defined to measure the achievement of the 2030 objective.

TARGETS 2030

- Increase productivity by 20%
- Reduce building renovation time by 50% at maintained quality and performance level
- Reduce by 40% the emissions of the construction process (machinery, vehicles, manufacturing) in line with EU targets
- Improve security of workers: 50% reduction in incidents, Zero fatalities
- 30% reduction in repair work
- 20% reduction of time & cost of interventions for maintenance
- 20% cost reduction in conservation
- Reduce vulnerability to natural / man-made aggressions by 20%
- Integrated Design and Delivery Solutions are accepted and normalised as mainstream procurement options in the EU
- Reduce the skills gap by a factor 3

The next table provides a synthetic view on the R&I priorities and related topics, with an indication on timeline, type of activities required, and nature of expected impact. The R&I priorities and topics are then described in the following sections, with a reminder of the related Targets 2030.

Figure 7 : R&I priorities and topics for objective "Prosperous construction ecosystem"

R&I priorities and topics	2020-2024	2024-2027	2027-2030	Nature of major impact
3.1 Cleaner, faster, safer and more cost-effective construction, retrofitting and commissioning processes				
Standardization framework and progressive regulation	*R&D/ Demo*			👥
Automation and mass-customisation of design and manufacturing processes	*R&D/ Integration/ Demo*			€
New services for on-site/off site surveillance and monitoring of buildings and infrastructures in construction and in use		*R&D/ Integration/ Demo*		€
Tools for better-informed decision making and risk management		*R&D/ Integration/ Demo*		€
3.2 Improved resilience and adaptability of the built environment				
Designs, materials and solutions to improve resilience & responsiveness of the built environment to disruptive events	*R&D/ Integration/ Demo*			👥
Designs for increased flexibility, adaptability and scalability of the built environment		*R&D/ Demo*		👥
Predictive and integrated maintenance solutions and processes		*R&D/ Integration/ Demo*		€
Lifecycle-based asset management and holistic approach of infrastructures		*Integration/ Demo/ Scaling up*		€
3.3 New contractual processes and partnerships				
New public and private procurement approaches supporting the implementation of innovations and the performance-based contractual approach	*Business models/ Demo/ Scaling up*			€
New business and financing models supporting the integration within the construction value chain and with other sectors		*Business models/ Integration/ Scaling up*		€
Tools for better-informed decision making on investment and improved risk management	*R&D/ Integration/ Demo*			€ 👥
3.4 Educational tools increasing the attractiveness and skills of the industry's careers				
New digital capabilities training for the sector, both at basic background and highly specialized levels	*Integration/ Demo/ Scaling up*			👥
Renewed academic curricula to adjust to industry needs and performance-based targets exploiting ICT tools	*Integration/ Demo/ Scaling up*			👥
Cocreative processes with all workers in the ecosystem	*R&D/ Demo*			👥

Legend: 👥 **Societal impact** € **Economic impact** 🍃 **Environmental impact**

Definitions of these impacts are provided in the Glossary of page 3-4.
Abbreviations used to describe the type of R&I activities are defined in page 5.

The next diagram provides an overview of the critical processes and technologies that will contribute to the industrialization of the construction industry and the related major applications, as detailed in the next R&I topics.

This diagram is intended to feed the interactions with the European Commission about all "manufacturing" topics to be covered by Horizon Europe, and their specific applications in the construction sector.

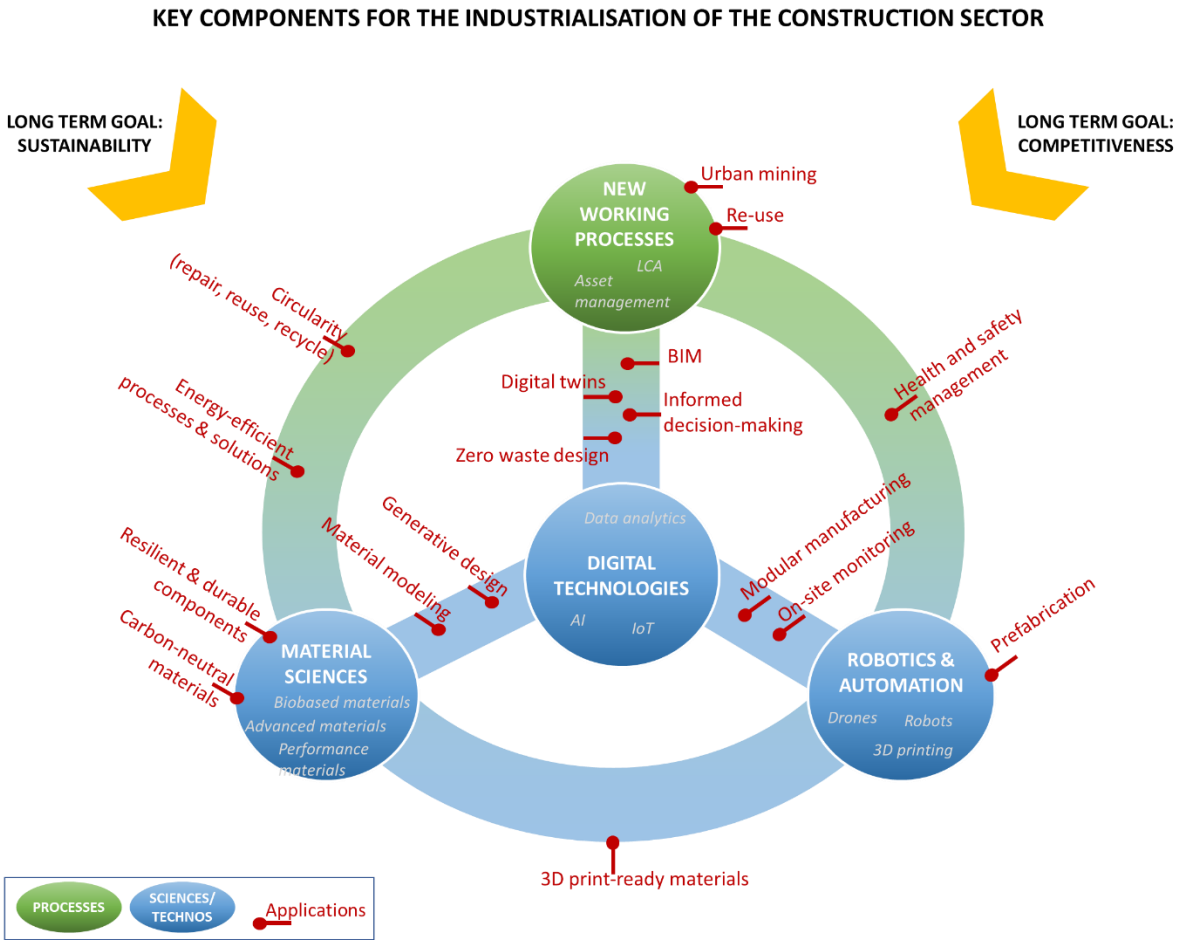


Figure 8 : Key components for the industrialisation of the construction sector

7.3. R&I 3.1: Cleaner, faster, safer and more cost-effective construction, retrofitting and commissioning processes

This R&I topic is the cornerstone of the industrialisation plan for the sector: the combined standardisation, automation and digitalisation of all processes from design to exploitation is a major source of economic gain.

Solutions exploiting robotics and automation in the manufacturing and construction processes, together with the adoption and massive use of digital technologies such as IoT, data analytics and artificial intelligence, must be developed and tested in order to demonstrate their profitability potential. *Smart manufacturing* shall be deployed to allow optimised processes (thanks to process data analytics), including modular design and customised fabrication, and maximised off-site assembly and appropriate logistic management. Modified and enhanced construction materials thanks to material modelling, and the use of new materials will contribute to more efficient, cost-effective and durable infrastructures. New construction processes combined with optimised materials usage will lead to faster deployment of the construction works minimizing the disturbance to the citizen. A holistic approach to the design of the urban space, above the ground and underground (geotechnical aspects) is also required. New services and processes must be developed on-site for improved safety, surveillance and operation of buildings and infrastructures. On the regulatory side, a progressive implementation of new regulations should be fostered, with early stage phases to test the new regulatory framework with volunteers, followed by the deployment of compulsory rules.

Target 2030
- Increase productivity by 20% - Reduce building renovation time by 50% at maintained quality and performance level - Reduce by 40% the emissions of the construction process (machinery, vehicles, manufacturing) in line with EU targets - Improve security of workers: 50% reduction in incidents, Zero fatalities

R&I topics
- Standards and regulation: standardization framework for data and models, testing methods and protocols, products; progressive implementation of regulation with prior local tests with early adopters; - Automation and mass-customisation of design and manufacturing processes (smart manufacturing, modular off-site construction or prefabrication, 3D printing, material modelling, swarm robotics, pop-up factories, etc.) - New services for on-site/off site surveillance and monitoring of buildings and infrastructures in construction and in use (drones, IoT) - Tools for better-informed decision making and risk management (geotechnical aspects, logistics, production process, tracking, supply chain traceability, etc.)

7.4. R&I 3.2: Improved resilience and adaptability of the built environment

This priority focuses on integrating all available knowledge, best practices, materials and technologies to build a safer, more resilient and durable environment. This includes designs, materials and solutions that contribute to better respond to man-made and natural threats such as floods, soil drying out, other climate-driven events and earthquakes; as well as those allowing more efficient and cost-effective

Target 2030
- 30% reduction in repair work - 20% reduction of time & cost of interventions for maintenance - 20% cost reduction in conservation - Reduce vulnerability to natural / man-made aggressions by 20%

surveillance, restoration and conservation of buildings and infrastructures.

New designs should as well serve the purpose of an increased flexibility, adaptability and evolvability of the built environment to respond to new needs of a fast-evolving society and account for the future impacts of climate change. In addition, recent advances in modelling the ageing and degradation of materials and structures should allow to generalise non-destructive diagnosis and new tools for predictive maintenance at much lower cost (reduced interruption time, optimised interventions). Managing the assets over their whole lifecycle and in connection with the other infrastructure networks (district heating, energy, water supply and sanitation, flood defence, transport) in a holistic approach to resilience will further contribute to the general objectives of safety, efficiency and durability.

R&I topics
- Designs, materials and solutions to improve resilience & responsiveness of infrastructures to (man-made, natural) disruptive events (including safety, prevention, detection, mitigation) - Cost-effective and durable materials, techniques, models and designs for improved surveillance, restoration and conservation of the built environment - Designs for increased flexibility, adaptability and scalability of the built environment (taking into account data from climate models) - Predictive and integrated maintenance solutions and processes (including ageing and degradation models and non-destructive diagnosis) - Lifecycle-based asset management and holistic approach of infrastructures (integrating the built environment with the other networks)

7.5. R&I 3.3: New contractual processes and partnerships for the construction sector

Target 2030
- Integrated Design and Delivery Solutions are accepted and normalised as mainstream procurement options in the EU

"*Don't tell us how to build it, rather what performances are expected*", so is the spirit of this R&I priority. Procurement and tendering must be rethought and tested in the perspective of performance targets, proposing new ways of measuring or assessing performances. While the generalisation of BIM and other digital tools allows to implement more efficient management and procurement methods like Lean and IDDS (Integrated Design and Delivery Solutions[18]), these advances, well implemented in the USA, are hindered by current rigid procurement mechanisms, very strictly regulated in most EU countries. Tendering processes shall also:

- shift away from the systematic "lowest cost solution" priority and give more room to innovations with yet limited track records, contributing to accelerate their learning curve and reduce their cost,
- allow and encourage more participatory processes, engaging all the stakeholders in the production value chain at the very early stages of the design process.

[18] *See proposed definition in Glossary section*

Empowering early participation of technical and non-technical stakeholders across all lifecycle stages from design to operation via new procurement and tendering models will ensure common goals and shared benefits to be the drivers for collaborative and inclusive production of the built environment.

Industry players must co-create new business models and financing schemes to better integrate their respective service activities, within and outside the construction value chain (as for example ICT-based platform services in construction). New business models for the sustainable management of cultural assets (preservation and restoration), involving more funds from private sources, need to be found. Finally, data analysis should feed the investment processes to allow rationalised decision-making and risk management.

R&I topics
- New public and private procurement approaches – including for infrastructures and cultural heritage- supporting the implementation of innovations and the performance-based contractual approach, - New processes, business models and financing mechanisms supporting the integration within the construction value chain and with other sectors, including integrated and participatory design and delivery processes - Tools for better-informed decision making on investments and improved risk management

7.6. R&I 3.4: Educational tools increasing the attractiveness and skills of the industry's careers

Target 2030
- Reduce the skills gap by a factor 3

This priority addresses the strong need to renew the full educational and professional pathway within the construction sector. A variety of EU funded projects is contributing to addressing the skills gap in construction industry, trying to up-skill the existing work force. However, the shortage of blue-collar construction workers is imminent and should be tackled in the near future. Scientific profiles also need to be attracted. Solutions include making the professions safer and more attractive for youth and the female workforce, which potentially could close the gap of youth unemployment and inequality at the same time.

Digital capabilities must be built, curricula and training techniques must be renewed, from state-of-the-art ICT tools (e.g. visualization, modelling) to historical building renovation. Life Cycle Thinking and asset management must be integrated in curricula through a cross-disciplinary approach. Beyond capacity building, all processes within the industry must initiate their transition towards more participative processes in order to retain workers and increase their commitments to quality and performance targets.

R&I topics
- New digital capabilities training for the sector, both at basic background and highly specialised levels - Renewed academic curricula integrating LCA and asset management and development of intuitive learning tools to adjust to industry needs, sustainability targets and a new culture of performance-based commitments - Co-creative processes with all workers in the ecosystem.

8. R&I priorities for objective: “Digitalisation”

The objective 2030 in terms of digitalisation, as an enabler for the other Goals 2050 and related objectives 2030, is reminder below.

8.1. Rationale: barriers and drivers

The construction sector is the economic sector with the lower digital intensity index in the EU and although many of the enterprises in the sector have already initiated their digitalization, in many cases they are still in the 1st level of the Digital Transformation[19]. ICT tools have been adopted to develop specific and isolated tasks, but these tools have no impact in the processes of the organization. For example, the progress monitoring of projects is based on data (sometimes digital data e.g. digital pictures, excel sheets) that are manually collected by the construction site management team.

Digital transformation will happen anyway, however the construction sector should strive to foster it and ensure that this transformation is made in a fair and inclusive way (i.e. involving all actors, from construction SMEs to end-users) to maximise its benefits for all. To do so, the barriers to be addressed include:

- **Data capture, storage and sharing**: these are key issues and it is one of the hardest to tackle (from a business perspective). Currently data are very disaggregated, and data ownership can create silos that result in not being able to perform a suitable playground to perform meaningful analysis. Open standards are so far poorly adopted, and proprietary data formats and languages still dominate the market.
- **High fragmentation of the value chain**: Building and infrastructure projects require a large chain of contractors and subcontractors, mostly SMEs, which represent 80% of the total value added of the whole sector[20]. Due to the need of proximity to the construction site, this chain has to be redefined for each project. Most of the companies in the chain are often playing standard tasks which are human intensive and not knowledge and technology driven, with stronger skills gaps towards digitalisation with respect to other manufacturing sectors. This overall results in a **low pace of innovations uptake** which if properly addressed may result in a huge potential to increase the productivity of the sector and the quality of its products. The very long life-time of buildings and infrastructures is also a challenge for the digitalisation which is characterised by much shorter time frames.
- **Data privacy and protection of personal data**: public acceptability of data collection and their commercial use is a major barrier to the development of data-based services. The digital transformation must therefore carefully account for the social perception of digitalisation.

[19] i.e. Business as Usual, see “The Six Stages of Digital Transformation Maturity”. Custom research by Altimeter Group on behalf of Cognizant

[20] In 2016. Source: EBC

Rather than a lack of acceptance, the reluctance may be related to a lack of awareness. Establishing the proper framework and guarantee proper exploitation of data is key for the digital transformation of the construction sector, in particular to support the trends towards servitisation and increased comfort.

- **Interoperability and integration**: digital models developed for buildings are not fully interoperable with models for infrastructure, and even less with those of other utilities such as water networks, district heating and other energy networks.

Regulatory, legal and market drivers to accelerate digitalisation include:

- Digitalisation of the construction sector is increasingly recognised as a potential game changer for the sector, and the European Commission has supported, promoted and developed several **policies and initiatives aiming to foster the digitalisation in the construction sector** (Strategy for the sustainable competitiveness of the construction sector and its enterprises (2012), the EU BIM Task Group and the upcoming EU Digital Construction platform[21])
- **BIM is a frontrunner** with regard digital innovation. Its use in construction projects is promoted by the EU directive on Public Procurement (2014), and several Member States have already made BIM compulsory in **public procurements**, which has been a main driver for BIM implementation. However, the adoption of BIM by the construction industry remains limited, showing a gap between policy and practice.

8.2. Targets 2030 and related R&I priorities and topics

The following targets are defined to measure the achievement of the 2030 objective.

TARGETS 2030

- □ Full interoperability of all systems (BEMS, active components, RES) within new and renovated buildings (Plug & Play)
- □ Full interoperability (with open standards) between different software (e.g. simulation, BIM, 3D printing)
- □ Standardised framework for data management
- □ 50 % EU cultural heritage in BIM model
- □ Public procurements are fully digitalised (BIM based) in all Member States
- □ Full data privacy and security for all EU citizens, including workers
- □ Full integration of infrastructures in BIM (City Information Modelling)
- □ Reduction by 10% of operational costs in logistics

[21] European Construction Sector Observatory (2019) Building Information Modelling in the EU construction sector

The next table provides a synthetic view on the R&I priorities and related topics, with an indication on timeline, type of activities required, and nature of expected impact. The R&I priorities and topics are then described in the following sections, with a reminder of the related Targets 2030.

Figure 9 : R&I priorities and topics for objective "Digitalisation"

R&I priorities and topics	2020-2024	2024-2027	2027-2030	Nature of major impact
4.1 Smart operation and maintenance of buildings and infrastructures				
EU-wide open databases and Data Management Platforms on the performance of the built environment	*Integration/ demo/ Scaling up*			€ 👥
Big data-based building and infrastructure real-time management, monitoring and maintenance, including cultural heritage	*R&D/ Integration/ Standardisation*			€
Digital decision-making tools on investment options	*Integration/ Demo / Scaling up*			€
4.2 BIM & Digital Twins for value chain integration with focus on SMEs				
Holistic data-based approach, from tendering to end of life	*R&D/ Integration/ Standardisation*			€
Digital innovation in procurements	*Integration/ Demo/ Scaling up*			€
4.3 Data privacy and security				
Data-based value-added services preserving privacy and security	*R&D/ Integration/ demo*			👥
Vulnerability and cybersecurity of digital assets	*R&D/ Integration/ demo*			👥
4.4 Better integration of the built environment with the urban space and mobility				
integrated information management at district and city level	*R&D/ Integration/ Demo/ Certification*			€
Development of integrated, multi-modal and multi-stakeholders travel information models	*R&D/ Integration/ Demo/*			👥

Legend: 👥 **Societal impact** € **Economic impact** 🍃 **Environmental impact**

Definitions of these impacts are provided in the Glossary of page 3-4.

Abbreviations used to describe the type of R&I activities are defined in page 5.

8.3. R&I 4.1 Smart operation and maintenance of buildings and infrastructures

New mechanisms (incl. protocols, platforms) to share the data across stakeholders, from design to construction to operation, are key to the development of new solutions and services for the smart operation of the built environment. Standardised methodologies for data management over the whole project life cycle, addressing the ownership of the data, its value and quality, are therefore required. Interoperability (with plug & play components) and robustness of sensors and tools are other prerequisites to the digitalisation of the operation and maintenance of buildings and infrastructures (for instance through Digital Twins).

Target 2030
- Full interoperability of all systems (BEMS, active components, RES) within new and renovated buildings (Plug & Play) - Standardised framework for data management - 50 % EU cultural heritage in BIM model

R&I topics
- EU-wide open databases and Data Management Platforms on the performance of the built environment (e.g. building stock observatory, including energy performances and vulnerability) - Big data-based building and infrastructure real-time management, monitoring and maintenance (Digital Twins, BIM, Artificial Intelligence), including cultural heritage

8.4. R&I 4.2 BIM and Digital Twins for value chain integration, with a focus on SMEs

The digitalisation of the construction sector is a huge opportunity to dramatically improve the integration within the value chain. The widespread adoption of BIM throughout the industry is the first step of the digital transformation. The private sector plays there a driving role.

Target 2030
- Public procurements are fully digitalised (BIM based) in all Member States - Full interoperability (with open standards) between different software (e.g. simulation, BIM, 3D printing)

Beyond BIM, Digital Twins, Big Data, Artificial Intelligence and blockchain also bring interesting prospects for decision-making tools and holistic approaches, from tendering to the end of life, including smart contracts. Data storage on materials, production process and compound properties will allow monitor materials durability during use, reuse and recycling.

R&I topics
- Holistic data-based approach, from tendering to the end of life (with BIM, Digital Twins, IoT, data analytics/ AI) - Digital innovation in procurements (BIM, smart contracts)

8.5. R&I 4.3 Data privacy and security

Target 2030
- Full data privacy and security for all EU citizens, including workers

The success of the digital transformation (and that of all the solutions and services it enables) is conditioned by public acceptance and a generalised uptake. Awareness raising and convincing are cornerstones of public acceptance, for instance by demonstrating the added-value of data-based services (e.g. safer environment, 'seamless' mobility services, etc.). In that sense, social sciences provide invaluable inputs. Some work is already initiated by the EC on measuring the ICT smart readiness of buildings (Smart Readiness Indicator under the revised EPBD) in view of raising awareness about the benefits of ICT in buildings, motivate consumers to accelerate their related investments. Another critical point is to guarantee that the digital assets, and the stored data, are safe against cyber-threats.

R&I topics
- Data-based value-added services preserving privacy and security - Vulnerability and cybersecurity of digital assets

8.6. R&I 4.4 Better integration of the built environment with the urban space and mobility

Target 2030
- Full integration of infrastructures in BIM (City Information Modelling) - Reduction by 10% of operational costs in logistics

Digitalisation can enable and support a better integration of buildings with the infrastructures and other urban networks (energy, water, waste management, communication, transport) and more generally the urban spaces. These different components, today often considered in isolation, need to become more integrated to promote a new continuity in the urban fabric (in the planning and operation phases, in the living and mobility patterns) to maximise synergies and improve the accessibility (in particular for the ageing population).

R&I topics
- Integrated Information Management at district and city level - Development of integrated, multi-modal and multi-stakeholders travel information models

9. Concluding remarks

The present Strategic Research and Innovation Agenda (SRIA) reflects a collective vision for of the future of the construction industry and the built environment, based on the expertise of key sector players within and outside the ECTP association, and on the lessons learnt from the ongoing Public Private Partner Energy *Efficient Buildings* (cPPP).

The SRIA delivers a **Vision on the development of the built environment until 2050** and defines a set of mid-term objectives in order to turn this vision into reality. It gives an overview of the main **environmental, societal, technological and industrial challenges** to be taken up by our sector in the coming decades.

As per our Vision, the built environment, from single buildings to districts interconnected through infrastructures, will evolve towards a fully user-centred, networked environment fostering sustainable living patterns and quality of life thanks to data-driven real-time management processes.

To that end, a full plan for Research and Innovation activities is proposed, structure **around 4 goals to 2030** that respectively address sustainability, industrialisation, user-centricity, and digitalisation as a cross-cutting and critical enabler.

The **sustainability goal** focuses on the solutions required to speed up the retrofitting of buildings and infrastructures, the shift to a life-cycle approach and the deployment of positive energy districts in view of a lower environmental impact of cities.

The **user centricity goal** addresses solutions for more participative design and operation of the assets, for the integration of ICT into buildings, infrastructures and networks for more comfort, inclusiveness and carbon neutrality, and the integration of biobased and advanced materials to improve the built environment's health and safety.

The **industrialisation goal** tackles the integration of new technologies into the manufacturing and construction processes (AI, automation, etc) and of new workflows (asset management) to improve industry performances in terms of cost, skills and environmental impact, for a more climate-resilient and adaptative built environment.

Finally, the **digitalisation goal** addresses the critical digital tools that are required to support the three previous goals, with focus on data models, standards, privacy and security.

A breakdown of the required EC funding to perform those R&I activities and meet the related targets is proposed accordingly.

The SRIA aims to provide guidance and support to the following stakeholders in the coming years:

- The European Commission, in its definition and strategic planning of the HORIZON EUROPE programme for Research and Innovation and the related Co-programmed Partnership "Build4People"
- Member States, in their identification of common Research and innovation topics of interest,
- Professional associations in their efforts towards integration, joint initiatives and collaborative projects,
- All stakeholders of the construction sector and the built environment, in their own strategy development towards more **competitiveness, sustainability and quality of life** for European citizens.